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SUPERABRASIVE INDUSTRY REVIEW

Featuring CVD Diamond and cBN

THIS ISSUE

2012 IDA Annual Meeting Review

IDA Announces INTERTECH 2013

A Growing Global Demand for CVD Diamond

New Concept Conditioner Made by An Engineered Surface Coated with CVD Diamond

Development of High Quality, Tailored CVD Diamond Using Hot Filaments

Diamond Production Innovation – Mass Production

Cubic Boron Nitride (cBN) Composite Coating, TuffTek® for Carbide and Ceramic Tools

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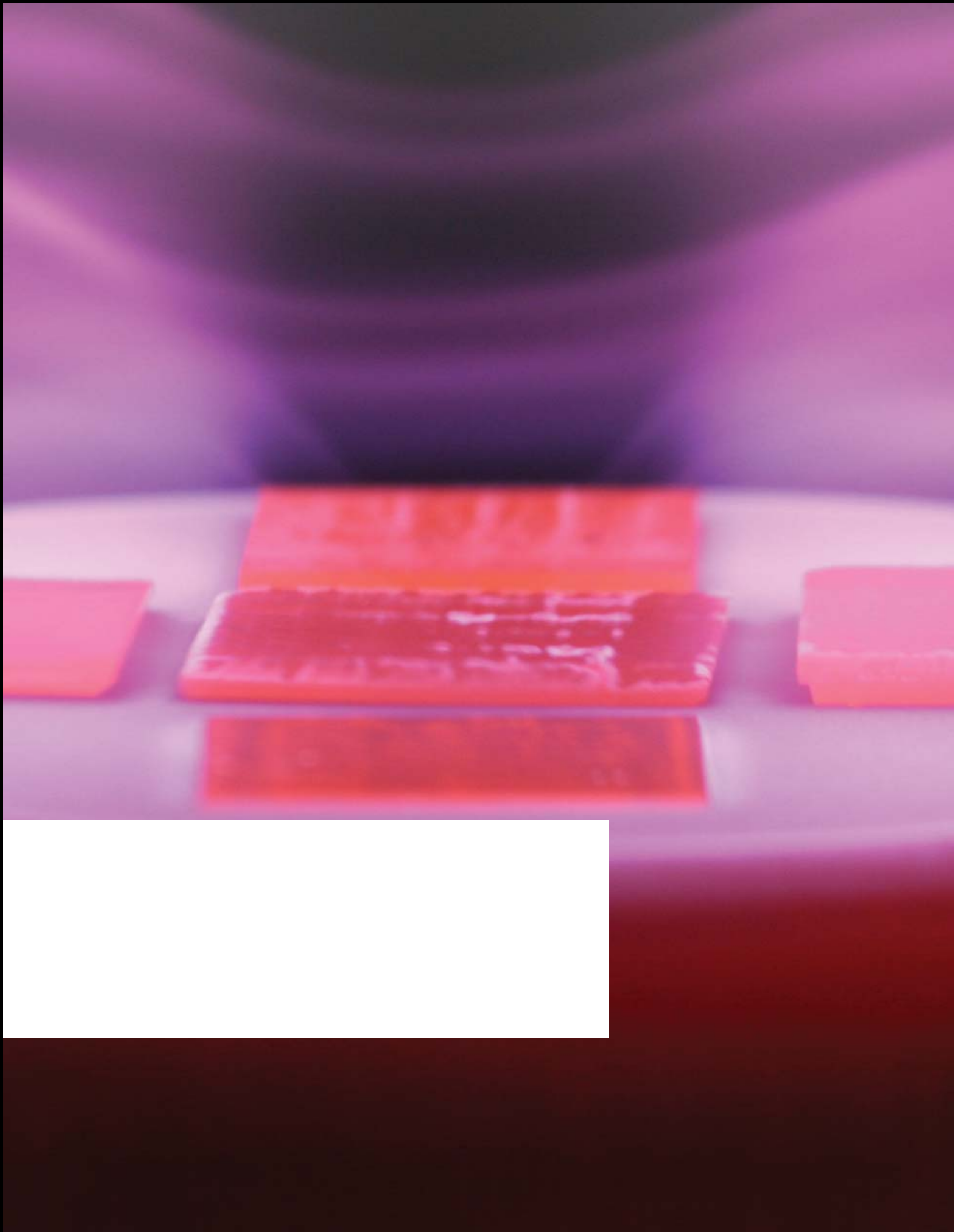

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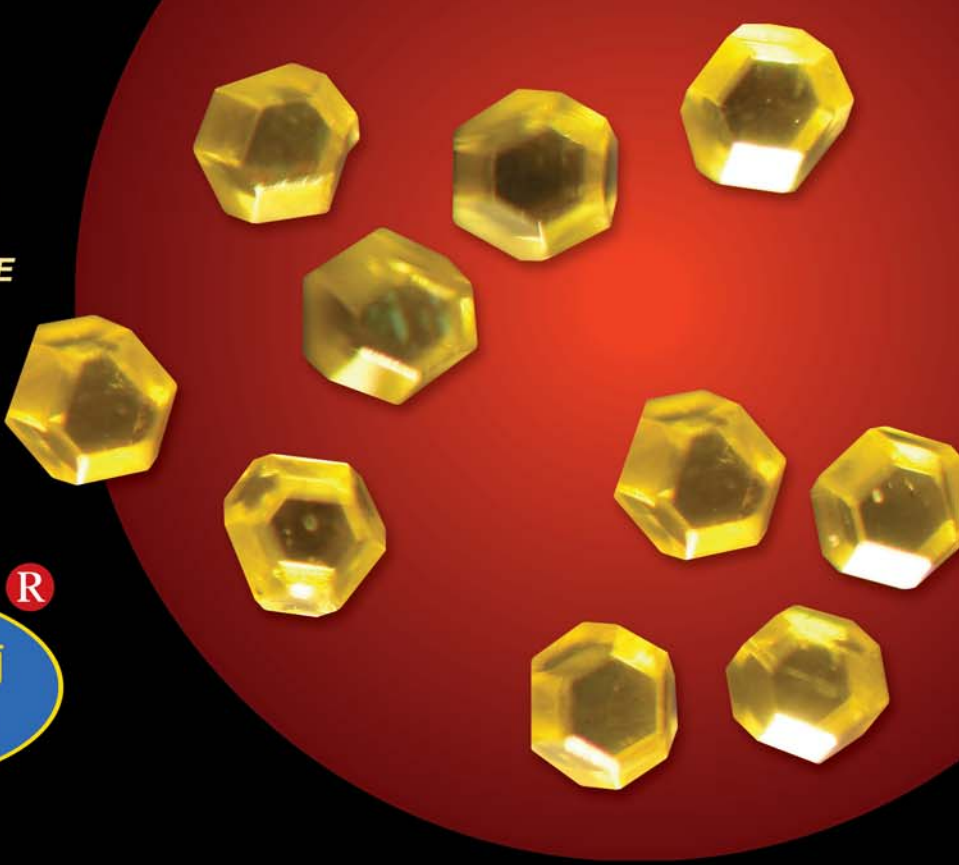

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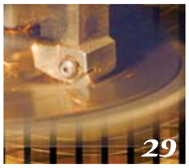

COVER PHOTO

Diamond deposition courtesy of Scio Diamond Technologies shows seeds with approximately 750 microns of diamond growth.

FINER POINTS is the longest running publication devoted exclusively to the understanding, selection and application of diamond, cubic boron nitride and related materials. It is edited for recipients who are involved in some way with these "superabrasives", either as providers of the materials, producers of products containing the materials or users of these products (e.g., grinding wheels, dressing tools, drill bits, saw blades, sawing wires, cutting tools, polishing compounds, CVD film products, etc.).

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A Finer Point of View…

As I start my term as President of the Industrial Diamond Association of America I am both honored and humbled. The IDA has a long history, going back some 66 years and my company is actually a charter member … Cleveland Industrial Tool Corporation, the predecessor of Citco, which is now Cinetic Landis Corp – CITCO/Gardner Abrasives was an original member of the IDA back in 1946. So we've been around for a while and I have strong ties to the Association and a tremendous desire for its continued growth.

The 1946 Membership directory only lists mailing addresses. In 1946 many companies did not have phones or the switchboard service was very poor. Today's directory not only lists phone numbers, but cell phones, emails and everyone's website! As we move from snail-mail to email and share daily thoughts through twitter, facebook and linked in and a number of other "social media", we not only have access and ease of communication but are barraged with communication overload.

The IDA has taken full advantage of the electronic media faze. Finer Points has embraced the Internet with an on-line version and dedicated website www.finerpointsmagazne.com. The Finer Points has gone from a simple newsletter in the early 50's to a trade magazine carrying news focused on the superabrasive industry.

The IDA has also seen the transformation of the machine tool operator classification in manufacturing. In the past the machine operator was an artist, able to hear when a part was being machined properly and his five senses guided an operation to deliver the final part with precision and accuracy. Today, computers and ultra modern machines can complete the manufacturing process and the operator is now a combination of computer programmer and technologist. The future of our entire manufacturing industry relies on recruiting and educating new operators that have the same pride and dedication as those of the past.

Training may be a word that's no longer appropriate. The new operators want "education". They want to know what is happening when an abrasive is working a material, what is critical in a wear mode or what makes one abrasive perform better than another on a given material … This is where our industry survives … "Education" on superabrasives is critical for the new breed of operator.

PRESIDENT
Edward E. Galen

The IDA has taken on this task and developed a comprehensive education package, one that not only challenges the operator but instills the pride in performance we have seen in years gone by. As current operators retire, where do we get the new breed to replace them and how do we instill the desire to enter into this profession? We need to work with high schools and trade schools to make this a priority. I believe education is the key and the IDA has taken the lead to make sure this is a priority for the next decade and beyond.

INTERTECH 2011 saw an extremely successful educational program for superabrasives with over 80 attendees per session. By popular demand, INTERTECH 2013 will continue with an even more comprehensive education program to target operators and manufacturing leaders at major end users … Superabrasives are instrumental to manufacturing profitability. From new superalloys and composites in aerospace to metal matrix composites and ceramics in automotive, superabrasives are the key. This is how we succeed and make manufacturing excellence and performance a priority for the 21st century.

With best regards,

Edward E. Galen, President
Industrial Diamond Association of America

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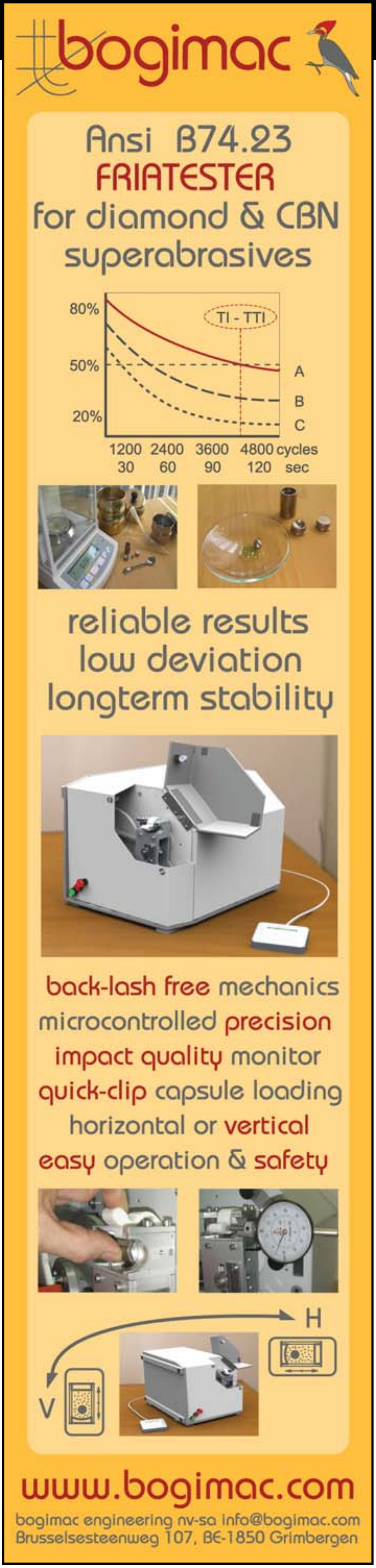
2012 IDA Annual Meeting Review

2012 BOARD OF DIRECTORS Left to Right: Scott Ries-Director, Ed Galen-President, Steve Griffin-Director, Chris Winkel-Past President, David Spelbrink-Director, Joe Connolly-Director, Aaron Nolan-Director, Troy Heuermann-Secretary/Treasurer, Mike Mustin-Vice President, Keith Reckling-Director

The 2012 IDA Annual Meeting was held this past month at the Hyatt Regency in Scottsdale Arizona. Members welcomed two new companies to the IDA, SCIO Diamond Technologies Corporation and Ulbrich Stainless Steels and Special Metals, Inc. The Meeting sessions were outstanding as attendees listened to three invited speakers. Gina Martin Adams of Wells Fargo, a frequent speaker at our meetings once again was excellent as she did her annual review and projections for the economy, especially the industrial businesses. Mitch Free a manufacturing insider and trade analyst of MFG.com, gave an excellent overview of manufacturing growth sectors and the positive signs that might lead to more companies reshoring manufacturing processes. We also were fortunate to welcome Adam Gordon from Wiley Rein, who spoke about recent litigation activities to protect US businesses from dumping products from foreign countries, especially in the diamond business. Mr. Gordon gave advice on ways to detect dumping and enforcing trade orders. All these speakers were very informative and let to some lively interaction. The meeting took a new turn as various newly established committees for the IDA took center stage in working sessions to discuss activities and generate action items on education, INTERTECH planning, Social media, Trade Association alliance, Membership and Finer Points content. At the Annual Meeting banquet sitting 2011 President Chris Winkel honored two IDA Members for their contributions. Joe Tabeling of Delaware Diamond Knives received the President's award for his contributions over the last few years as a Board Member, Officer and his specific contribution to setting up a new finance and reporting system for the IDA. Chris also awarded a Lifetime Membership Award to Wilson Born of National Diamond Research. Wilson was IDA President in 1986 and has contributed greatly to the growth and prosperity of the IDA through his years of service. Many IDA Members stood up to point out some of Wilson's contributions and strong support of the IDA over the years. The new Officers and Board for 2012 were introduced and everyone enjoyed a very productive meeting and social events.

Gina Martin Adams of Wells Fargo informed attendees of economic issues.

Attendees at the meeting took full advantage of working sessions and events to discuss issues and formulate business plans.



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THE FUTURE OF SUPERABRASIVES

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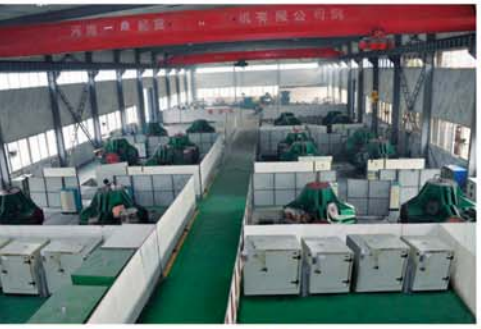
Mr. Han Jun, President and CEO of BESCO Superabrasives
Mr. Chris Winkel, President and CEO of WWSA
Mr. John Chalvadakis, Operations Manager of WWSA

- WWSA (Worldwide Superabrasives, LLC) and our joint venture partner, BESCO Superabrasives, proudly announce the expansion of our manufacturing facility in Kaifeng, China.
- WWSA/BESCO, which was founded in 2008, has made a significant investment to increase our plant capacity by over 80% to 60,000 square feet to meet customer demand.
- Included in our expansion is our new superabrasive raw material catalyst production facility—continuing our goal of controlling every part of the superabrasive manufacturing process.
- WWSA/BESCO will produce over 140,000,000 carats of the highest quality resin bond industrial diamond and Cubic Boron Nitride (CBN) in 2012 at our Kaifeng factory.
- WWSA/BESCO will increase the expansion of our manufacturing capacity to no less than 180,000,000 carats by the end of 2013.
- Recent reports indicate that approximately 90% of superabrasive raw materials are manufactured in China—regardless of the name on the label.
- WWSA/BESCO is in a very powerful position for many years into the future as a manufacturer of the highest quality superabrasive raw materials and a provider of world-class technical support, product delivery and customer service.
- IN SUMMARY, WWSA/BESCO will play a significant role in the future of the supply of superabrasive raw materials.



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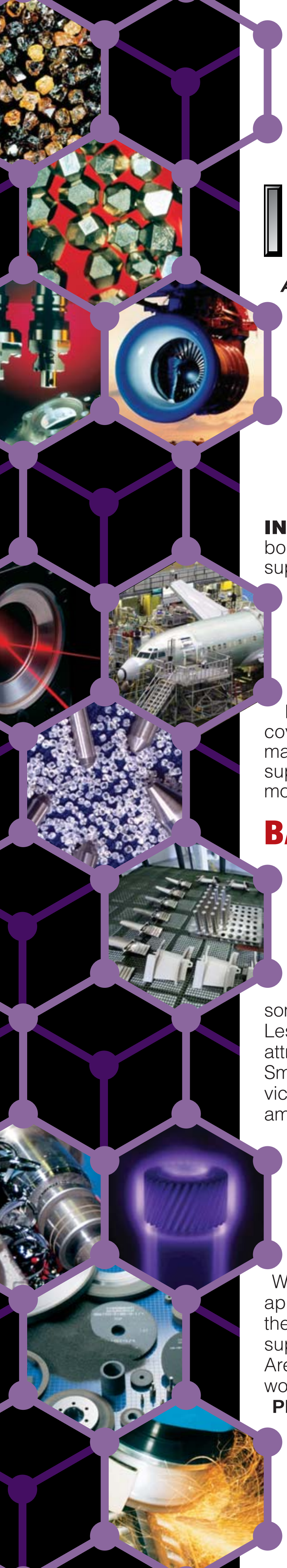

The Industrial Diamond Association of America Announces INTERTECH 2013 May 6, 7 & 8

INTERTECH 2013

An International Technical Conference on Diamond, Cubic Boron Nitride and their applications.

www.intertechconference.com

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May 6, 7 & 8, 2013

INTERTECH 2013 WILL BE THE FEATURED CONFERENCE FOR NEW TECHNOLOGY AND APPLICATION DEVELOPMENT OF SUPERABRASIVES AND SUPER-HARD MATERIALS FOR AEROSPACE

INTERTECH 2013 is the leading International Technical Conference on industrial diamond, cubic boron nitride, polycrystallines, CVD diamond, Nanodiamond and other materials classified as superabrasives and ultra-hard materials. **INTERTECH 2013** will feature leading experts representing international suppliers, manufacturers, research facilities, academia, end-users, machine tool builders and the scientific community with a focus on **Aerospace** applications.

COMPREHENSIVE EDUCATION SESSION

"Superabrasive and Ultra-Hard Material Essentials and Applications"

By popular demand **INTERTECH 2013** will once again offer, a concurrent one-day session covering the history, characteristics and proper application for diamond and cubic boron nitride materials. This session is a recently updated educational package to address the essentials of superabrasives and ultra-hard materials for those new to the industry or those who wish to become more familiar with the industry and its critical materials and applications.

BALTIMORE HARBOR IS A MAJOR ATTRACTION ...

This sensational event will be held in Baltimore, Maryland USA at the Hyatt Regency Inner Harbor. The Hyatt is conveniently located on Baltimore's Inner Harbor, the centerpiece of downtown Baltimore. The Inner Harbor is a vibrant and beautiful waterfront area surrounded by restaurants, attractions and shops. In just a few city blocks, you can discover an expansive collection of dinosaurs at the Maryland Science Center; wander through the pop culture icons of your past at Geppi's Entertainment Museum or explore exotic jellyfish, sharks and other creatures from the deep at the National Aquarium. Attendees of **INTERTECH** will want to set some time aside to visit Washington DC the capital of the United States. Less than an hour drive from Baltimore makes Washington a major attraction for attendees. Famous for its historical buildings, the Smithsonian Institute, memorials, statues and shrines, no trip to this vicinity would be complete without a tour of Washington DC for an amazing once in a lifetime experience. **INTERTECH 2013** will be a rewarding technical experience complimented by a trip to the world-famous and historic cities of Baltimore and Washington DC. All this proves **INTERTECH 2013** will be a "have to attend" conference!

YOU CAN BE A PART OF THIS EXCITING EVENT!

We are now soliciting commercial and technical papers of approximately 30-45 minutes in length that address the research of these super-hard materials as well as the dynamics and application of superabrasive systems in Aerospace and other industries as well (see: Areas of Consideration) with a focus on new technology, tooling, workpiece materials, machines and applications related to increased **PRODUCTIVITY** and **PERFORMANCE**. Consideration for papers is being made at this time and abstracts are now being accepted; contact us today to be considered. This will be the most comprehensive event ever held on superabrasive materials for Aerospace and similar industries!

Photos of Baltimore for INTERTECH 2013 courtesy of Baltimore Convention & Tourism Bureau.

AREAS OF CONSIDERATION FOR PAPERS WITH A MAJOR FOCUS ON SUPERABRASIVES USED IN AEROSPACE APPLICATIONS

AEROSPACE
- Manufacturing
- Rebuilding

MACHINE TOOLS
- Development
- Innovations
- Advancements
- Superabrasive

RESEARCH & DEVELOPMENT
- New Crystals & Abrasives
- New Coatings
- Bond Development
- Testing/Gauging
- Tool Fabrication
- Materials
- Tooling
- Application Development
- Film (CVD & PVD)
- Magnetorheological Finishing
- Electrolytic In-process Dressing (ELID) Mirror-Surface Grinding
- Nanotechnology

TOOLING
- Grinding Wheels
- Cutting Tools
- Drill Bits

WORKPIECE MATERIALS
- High Tech Ceramics
- High Silica Aluminum
- Glass
- Thermal Sprays
- Superalloys

OTHER NEW TECHNOLOGY & APPLICATION DEVELOPMENT

OTHER INDUSTRIES AND TOPICS FOR CONSIDERATION

AUTOMOTIVE
- Parts Manufacturing
- Gears
- Wheels
- Transmissions
- Engines

CONSTRUCTION/HIGHWAY
- Concrete Aggregates
- Highway/Runway
- Renovation
- Block Grinding/Polishing

ELECTRONICS
- Disc Texturing
- Wafer Mfg.
- Polishing
- Optic Windows
- Semiconductors
- Heat Sinks

EMERGING TECHNOLOGY
- CVD Diamond
- Nanodiamond
- New Crystals
- Coatings

GLASS
- Lens Generation
- Polishing
- Pencil Edging

MACHINE TOOLS
- Advancements
- Superabrasive Adaptation

MEDICAL
- Surgical Knives
- Prosthesis Fabrication

MINING/DRILLING
- Drills & Bits
- Application

OPTICS
- Polishing
- Lens Generation

RESEARCH & DEVELOPMENT
- HPHT Technology
- Pressing Equipment

TOOLING
- Grinding Wheels
- Cutting Tools
- Sawblades
- Drill Bits

WEAR PARTS
- Rests
- Anvils
- Nozzles

WIRE DRAWING
- Single Crystal
- PCD
- Manufacturing

WOODWORKING
- Hard Woods
- Fiberboard
- Laminates
- Composites

OTHER NEW TECHNOLOGY & APPLICATION DEVELOPMENT

WATCH FOR INTERTECH 2013 ON-LINE

As you can see by the areas for paper consideration, diamond and cubic boron nitride are not just being used as abrasives in traditional applications. Today, superabrasives and ultra-hard materials are making inroads in electronics, medical, cosmetics and literally every other industry where the characteristics of diamond and cubic boron nitride can affect performance or provide higher strength or new capabilities. As an **INTERTECH** attendee you will learn how these new products and applications are being developed, where super-hard materials are being used and how you can apply these systems in new and innovative ways. Visit the **INTERTECH 2013** website: www.intertechconference.com for additional information on: ● CONFERENCE REGISTRATION ● ABSTRACT SUBMISSION ● LOCATION & TRAVEL ● SESSIONS & SCHEDULES ● PAPER GUIDELINES ● VISAS AND INVITATION LETTERS ● SPEAKERS & TOPICS ● TABLETOP DISPLAYS ● KEYNOTE ADDRESSES ● ORGANIZING COMMITTEE CONTACTS

On-Line submission of abstracts is now available at www.intertechconference.com. If you wish to present a paper, you can also send a one or two paragraph abstract of your paper topic via email, fax or regular post to: Terry M. Kane, Chairman • INTERTECH 2013 • P.O. Box 29460 • Columbus, Ohio 43229 • Telephone: 614-797-2265 • Fax: 614-797-2264 • e-mail: tkane-ida@insight.rr.com

ABSTRACTS WILL BE ACCEPTED FROM JULY 1, 2012 THROUGH JANUARY 1, 2013

We will reply to all submissions. Come join us! **INTERTECH** has the tradition of being the most comprehensive event held on superabrasives and ultra-hard materials.

(PLEASE PRINT CLEARLY AND FILL OUT COMPLETELY. *INCLUDE ABSTRACT*)

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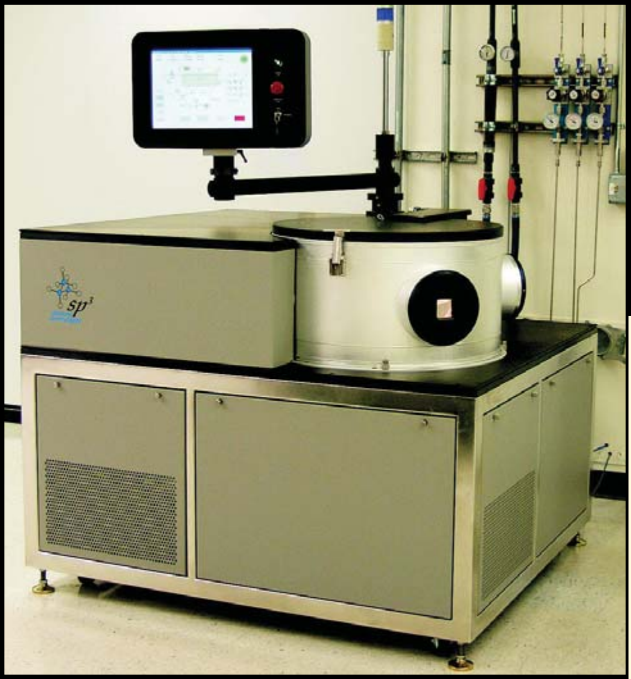

FIGURE 1 – Single Chamber Hot Filament CVD Deposition System

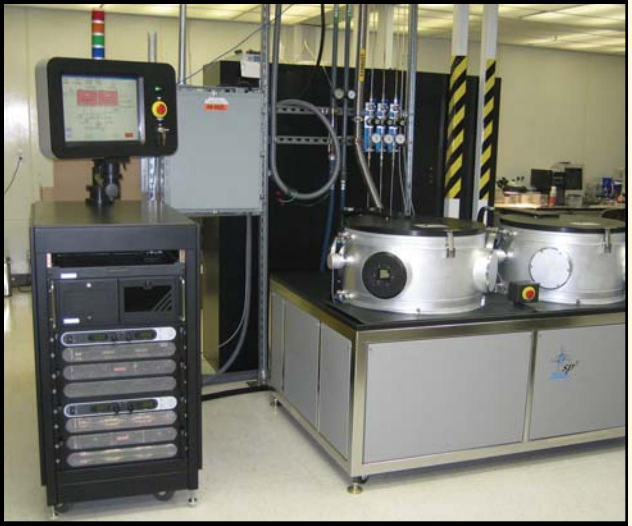

FIGURE 2 – Dual Chamber Hot FIlament CVD Deposition System

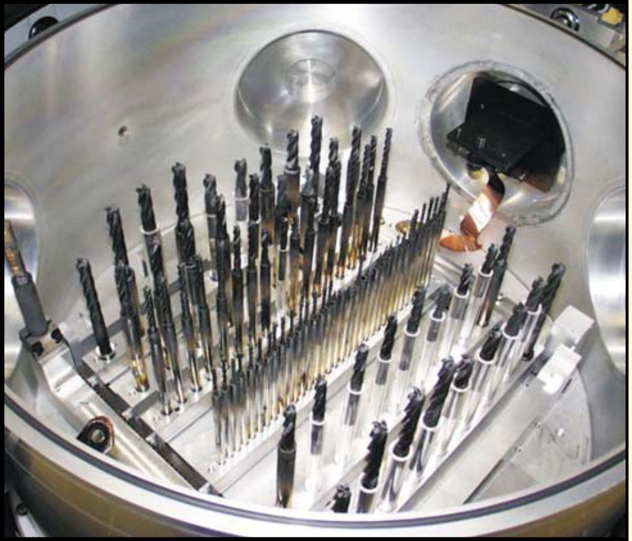

FIGURE 3 – Chamber Filled with Carbide End Mills, Freshly Coated with CVD Diamond

A GROWING GLOBAL DEMAND FOR CVD DIAMOND

By Valerie Singer, Product Manager, sp3 Diamond Technologies, Inc.

A The idea of CVD diamond as a cost-effective material of choice has become a reality. As Chemical Vapor Deposition (CVD) diamond becomes more and more commercially available via improvements in manufacture throughput, industries can now take advantage of the superior performance characteristics of diamond (durability, stiffness, strength, high thermal conductivity, and its electrical isolation properties, to name a few) with a lower material cost. Global market demand for hot filament CVD diamond and CVD diamond deposition equipment continues to grow, with emphasis in cutting tools for machining non-ferrous materials, MEMS devices for electronics and as an integrated thermal spreading layer of active circuits, and for chemical mechanical planarization (CMP) of semiconductor wafers. sp3 Diamond Technologies began designing CVD diamond equipment in 1993, with the specific goal of developing processes and products that would exploit the many unique properties of diamond. One of the main challenges the company faced was selecting a technical path that would provide for reliable, cost effective manufacturing on a production scale, day after day. After much analysis the path selected was hot filament CVD, as this was clearly the best path to cost-effective large area deposition in two and three dimensions. sp3 Diamond Technologies offers two commercial hot filament CVD deposition systems: the single chamber sp3 Model 655 (Figure 1) and the dual chamber Model 665 (Figure 2). Both of these hot filament systems can deposit a wide range of polycrystalline CVD diamond films, both nanocrystalline and micro-crystalline, from as thin as 200nm to as thick as 50 microns over an area approximately 350mm by 375mm. Both systems utilize fine wire filaments (0.12mm in dia.) in a cold wall aluminum chamber with a typical total system input power between 35 kW and 70 kW. The system's filaments are horizontal and can be arranged in a two-dimensional or threedimensional array. A sophisticated process controller provides for complex deposition recipes with up to 59 discrete steps. This high degree of program control is critical for the proper management of orderly startup, nucleation, growth, shut down and (most importantly) safety. sp3's hot filament systems use a programmable process controller, making it a simple task to vary the grain size as well as other properties of the grown diamond films. Uniformity is an area where sp3's hot filament reactors have clearly demonstrated their superiority over both microwave and DC torch approaches. A typical reactor load in a single chamber hot filament system can consist of several hundred cutting inserts, over 100 round tools, or single 300mm silicon wafer. sp3's hot filament reactors have the advantage of uniform temperature across the entire deposition area. In contrast, microwave reactors and DC torches create a sphere or plume of energy that is hotter at the center than at the edge. System designers try to compensate for these effects by rotating the substrate in an attempt to normalize deposition temperatures. This additional rotation adds complexity and cost, reduces reliability and can often be a source of contaminants. Both the Model 655 and 665 successfully avoid these pitfalls. The Model 665's dual chamber design offers double the throughput of the

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Model 655 single chamber design, further lowering the cost of ownership while still delivering the identical CVD diamond film characteristics, deposition rate and process uniformity as the single-chamber Model 655. sp3's Model 655 and 665 hot filament diamond deposition systems can produce uniform diamond films for a wide range of market applications.

The demand for thin film diamond on carbide cutting tools remains strong, with recent growth in the greater China market. China is acknowledged as one of the largest country in terms of industrial production, with a rising need for high quality cutting tools. The Freedonia Group, Inc., an industry market research firm, predicts that the demand for machine tools in China will grow 14.2 percent annually to a little over $61 billion in 2014. This robust growth will boost China's present position as the world's leading consumer and producer of machine tools. The Chinese government has set new strategic goals in their 12th five-year plan, including achievements in scientific development, which means that the Chinese government can be expected to dedicate an increasing amount of resources towards research and development activities. sp3 Diamond Technologies is helping to respond to this need by its recent shipment of a Model 655 Series HF CVD deposition system to China for cutting tool applications. The Model 655 system offers an industryleading solution for manufacturing nano- or micro-crystalline diamond films on carbide cutting tools, providing precise and repeatable diamond deposition for production applications (Figure 3).

CVD diamond coated tools take advantage of diamond's amazing hardness and resistance to abrasion, resulting in longer tool life, more accurate cuts and better finish on a work piece. China's increasing need for quality cutting tools and sp3 Diamond Technologies' position as a leading manufacturer and exporter of diamond deposition equipment is synergistic. There are also multiple applications for thin film diamond in Micro-Electro-Mechanical Systems (MEMS), as well. According to the MEMS Journal, the total market for MEMS devices is around $9.5 to 10 billion per year and it is expected to grow at 12 to 15% for the next few years. At the recent MEMS Business Forum 2012 in Santa Clara, CA, it was predicted that the MEMS market could potentially grow to $100 billion and 1 trillion MEMS devices per year by 2025. Potential applications include oscillator membranes, sensors, SAW devices, electrodes, display/optical systems, data storage, power systems and corrosion resistant coatings (Figure 4).

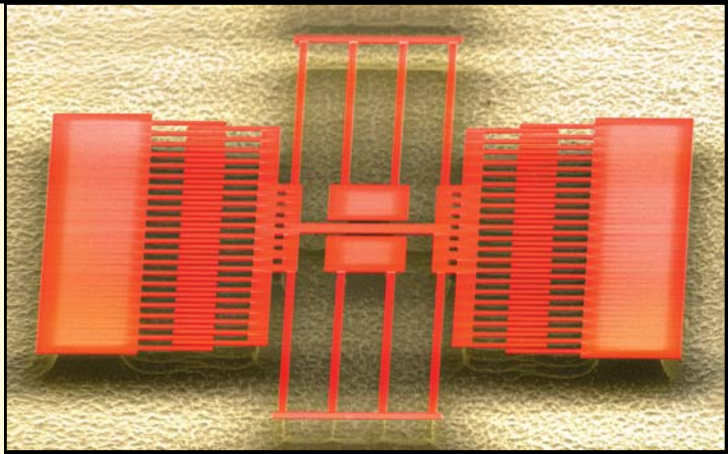

FIGURE 4 – ***A MEMS structure built from an sp3 diamond-on-silicon wafer (Photo courtesy of UC Berkeley)***

Of particular interest are MEMS devices for RF. Current cellular phones support three to four radio frequency bands. As cellular technology develops, the cell phones of the future can be expected to have five to ten bands, which will directly impact the complexity and power demand of the device. MEMS resonators vibrate at precise frequencies and have the ability to reject signals with certain frequencies while allowing others to pass. This ability creates a "band-pass" filter: a device that can pass selected frequencies through a cell phone's circuitry while rejecting others. Band-pass filters make it possible for devices to transmit signals with minimal interference and maximum efficiency, which is critical for cell phones and other wireless electronics. However, with the increased transmission efficiency comes an increased power load. MEMS silicon devices coated with thin film CVD diamond have proved to make excellent material for resonators. CVD diamond boasts not only excellent acoustic velocity but also superior thermal conductivity, making it a natural material for use in MEMS resonators. Researchers at UC Berkeley's Marvell Nanofabrication Laboratory recently took delivery of a sp3 Model 655D hot filament reactor and have been able to successfully produce high quality, cost-effective thin film diamond on silicon wafers suitable for MEMS devices. One particular recent success was an application in which UC Berkeley researchers used the Model 655 hot filament reactor to successfully grow microcrystalline (MCD) CVD diamond on a silicon capacitive-comb transduced micro-mechanical resonator with a Q of 146,580 at 232.441 kHz: this was three times higher than the previous mark for microwave plasma CVDbased devices. Additionally, contour mode disk resonators fabricated in the same hot filament CVD film and using material-mismatched stems demonstrated a Q of 71,400 at 299.8 MHz, which is the highest series resonant Q measured at this frequency for an on-chip room temperature MEMS resonator. UC Berkeley's research demonstrates the vast potential of diamond film as a cost-effective material of choice in the batch production of high-frequency on-chip resonators. Clearly sp3's hot filament diamond deposition technology will encourage and enable the adoption of CVD diamond film in a growing range of applications for the MEMS market.

CVD diamond also has a potential role to play in GaN power devices. Per market analyst Yole Développement, the GaN power device industry will potentially reach a billion dollars in revenue by 2019. High power semiconductor devices that generate a lot of heat (such as those in radar applications) run into the problems of limited performance and lower reliability. The challenge is finding a way to minimize the heat near the junction/channel of the transistor. Device designers have been turning to GaN HEMT at the wafer-level with some success in an effort to boost the

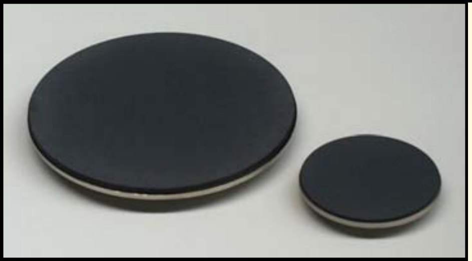

FIGURE 5 – Two Semiconductor CMP Pads with a CVD Diamond Surface

electrical efficiency of a device, but still face the difficulty of dealing with extreme heat. CVD diamond boasts excellent thermal conductivity; consequently, CVD diamond thin films would be an ideal thermal layer material for high power/high frequency semiconductor devices. Deposition systems such as sp3's Model 655 and 665 can successfully combine GaN growth on silicon with a CVD diamond heat spreader structure grown into the silicon wafer using known SOI fabrication technology. The use of CVD diamond directly below a GaN FET channel can lower the extreme temperatures in active regions, thus improving the performance and reliability of a device. The use of silicon on diamond (SOD) substrates with a built-in CVD diamond heat spreader layer is possible in part due to the advances in diamond deposition manufacturing technology that sp3 has developed over the last decade.

CVD diamond continues to have a steady demand in the chemical mechanical planarization (CMP) market. According to Techcet Group, LLC, the forecast for the pad market is estimated to be $612M by 2016. CVD diamond is an ideal material for CMP pad conditioners due to its wear characteristics, chemical inertness and range of abrasive characteristics. CMP use has escalated in semiconductor manufacturing in terms of the number of process steps using CMP, the increasing number of metallization layers and the number of materials being polished. These factors are driving the requirement for CVD diamond-based conditioning that delivers finer line widths and compatibility with the increasing complexity of slurries and pad textures. sp3 has successfully coated silicon wafers using hot filament technology (Figure 5) for the past fifteen years and utilized this expertise to pioneer a CVD diamond based pad conditioner for preparing the pads used in the chemical mechanical planarization of semiconductor wafers in the late 90's. The pad conditioners are supplied in both 50mm and 100mm diameters. This product line was later sold to a CMP focused company, has had some significant market success and led to the continued improvements needed to address sub- 35nm line widths. sp3's Model 655 and 665 hot filament CVD diamond deposition systems have been proven to produce quality, uniform diamond films at a reduced material cost for a wide range of applications. The reliability and repeatability of CVD diamond deposition was established with sp3's Model 655 and double-throughput has been achieved with the Model 665. Both systems will continue to make the commercial availability of CVD diamond film a reality in a wide variety of markets and correct the mistaken perception of diamond as an expensive material. ●

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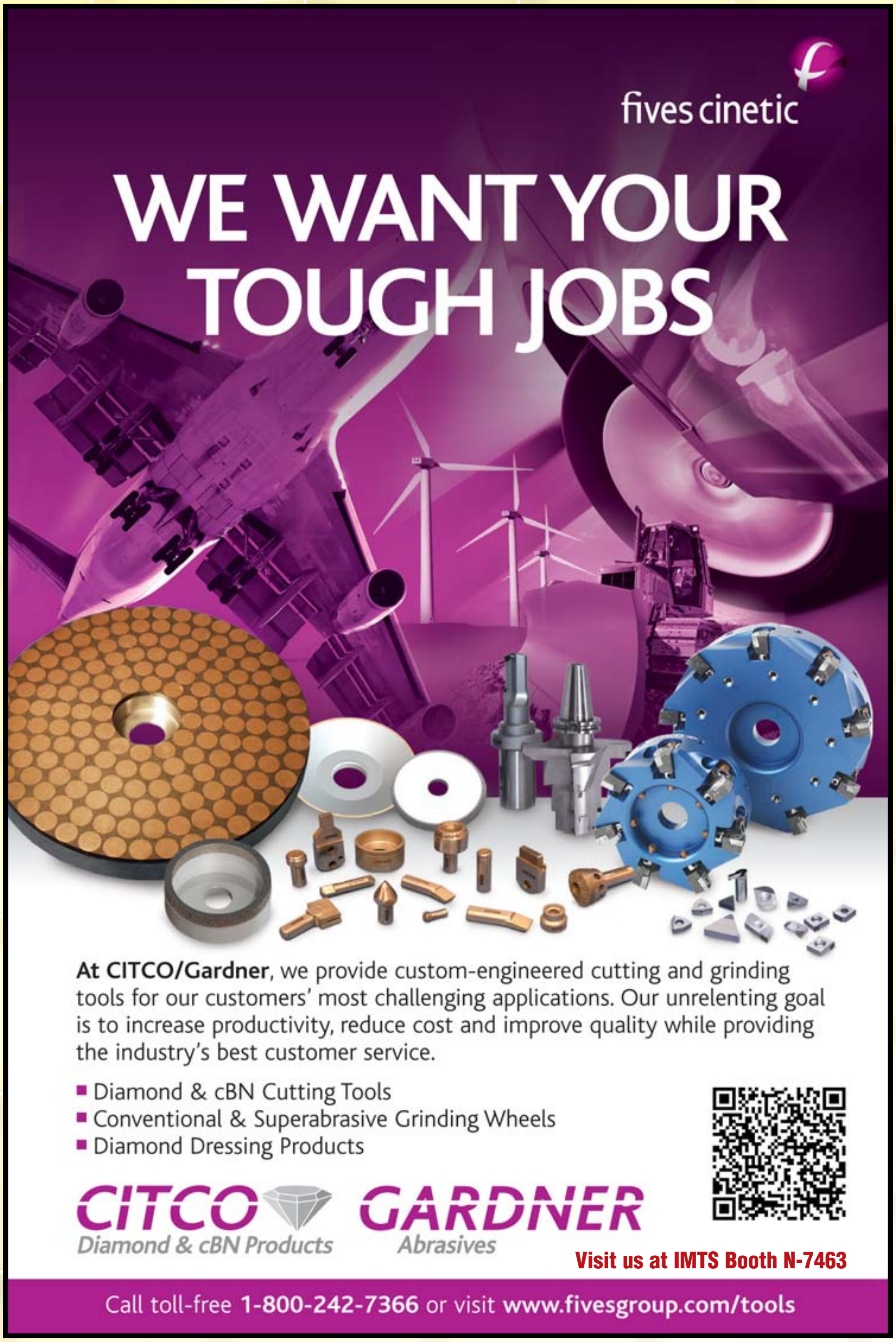

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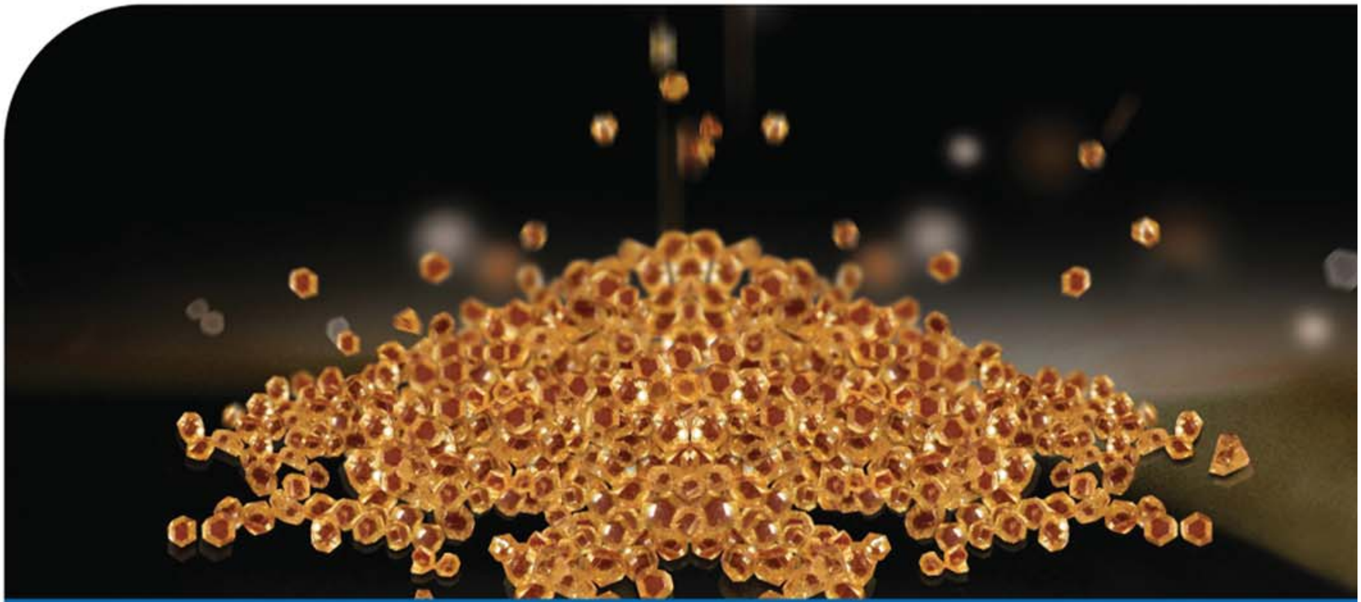

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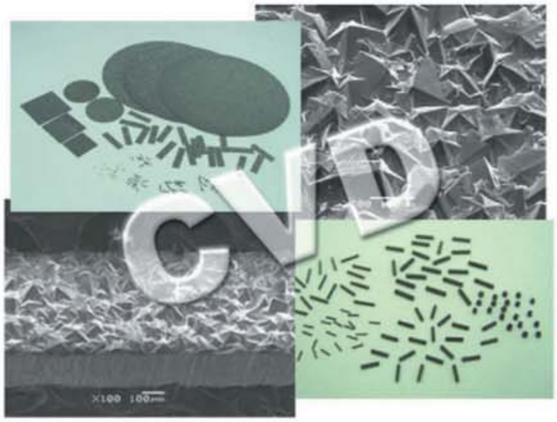

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NEW CONCEPT CONDITIONER MADE BY AN ENGINEERED SURFACE COATED WITH CVD DIAMOND

DAVID SLUTZ, Morgan Technical Ceramics

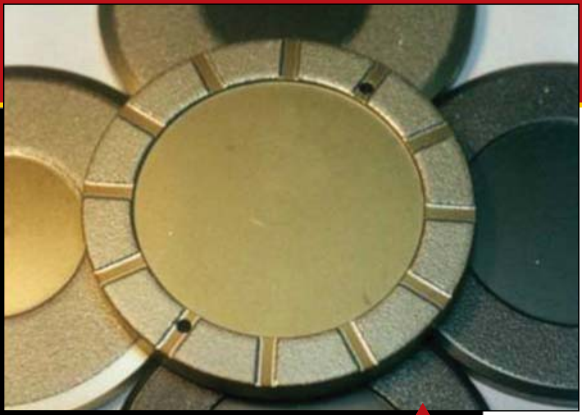
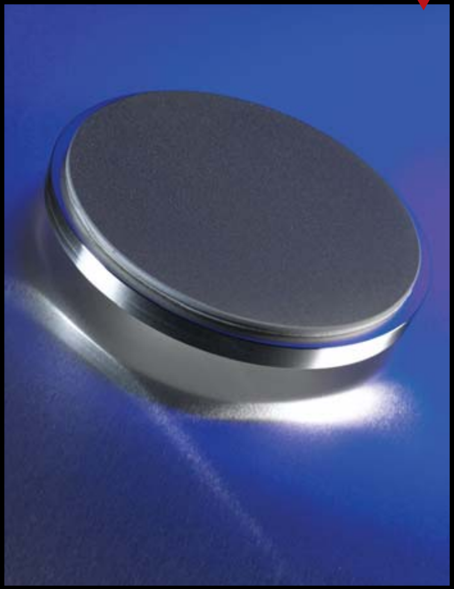


Figure 1: Convention CMP Conditioner

Figure 2: CMP Conditioner made using CVD Diamond Bond Matrix



Chemical Mechanical Planarization (CMP) is a high tech lapping process used in the manufacture of semiconductor wafers. The process not only polishes the surface of a wafer to a high surface finish, it also provides a super planar surface for the next step in the manufacture of semiconductor devices. CMP is performed on specially design tools manufactured for this specific purpose.

All CMP polishers have the same basic components in order to accomplish this task. There is one or more platens with a pad on top that rotates, a wafer head that holds the wafer and applies a down force to the pad surface, a slurry distribution system to distribute slurry on to the pad surface, a conditioner arm which holds a CMP conditioner that rotates and sweeps across the pad surface refreshing the pad surface.

There are three major consumables in the CMP process.

1) Slurry- provides the chemical reactions on the surface of the wafer and solid particles for mechanical interactions with the wafer surface.

2) Pad- usually made out of polyurethane which holds the slurry and provides a surface for the chemical and mechanical interaction with the wafer.

3) Conditioner- used to dress the surface of the pad continuously refreshing it by removing spent slurry and debris and conditioning the surface to a consistent texture.

The conventional CMP conditioner, figure 1, is typically a 4″ round disk with one surface containing diamond grit adhered to the surface with a metal bond. Historically the metal bond has evolved from electroplated nickel to either sintered metal or brazed metal. This evolution has greatly improved the diamond retention, by forming a chemical bond to the diamond grit instead of mechanically locking the diamond in place.

However, there are still drawbacks using this design principle. Many CMP processes use low pH slurries or slurries with chemistries that react with sintered metal and braze alloys. Research has shown, that over time the metal to diamond bond is weakened and the diamond grit can then fall out of the conditioner. Loose diamond grit in a CMP polishing process is detrimental in that it results in scratches on the wafer causing huge yield losses. More advanced CMP conditioners, figure 2 uses CVD diamond as the bond matrix to hold the grit to the conditioner surface.

This has many advantages over the metal bond matrix such as, no diamond pullout due to strength of bond matrix to diamond grit particle, no bond matrix corrosion, and no bond matrix erosion. In addition, the CVD diamond bond matrix is inert to all CMP slurries so there is no contamination to the CMP process coming from conditioners using CVD diamond as a bond matrix.

A good analogy to understand CMP conditioners is to consider them as “high tech sandpaper”. For example when sanding down a piece of wood, coarse sandpaper will remove more wood from the surface in less time than will fine sandpaper. However, coarse sandpaper will leave the surface rough where as fine sandpaper will leave the surface smooth. This is very much the same for CMP conditioners. For coarse diamond grit, the conditioner will typically have a higher pad cut rate while a fine grain conditioner will leave the pad surface smoother.

Therefore there is a relationship between pad cut rate and pad surface texture based on the type of conditioner used. Figure 3 depicts this relationship. Note that as the grit size decreases so does the pad cut rate and pad texture. This relationship of conditioner design to pad cut rate and pad textures also depends on what pad is being used. So selection of a CMP conditioner is dependent on the pad and what pad texture is need for the particular CMP process.

Ideally you want a conditioner that provides the minimum of pad cut rate to optimize the life of the pad, yet create a pad texture that gives the desired CMP performance.

Advanced nodes are requiring smoother and smoother pad texture to reduce the effects of dishing and erosion. Dishing and erosion are two terms used in CMP referring to surface phenomenon that result in the surface not being planar. Both of these phenomena have become more prevalent as the node size has reduced. However, dishing and erosion also is directly related to the pad texture. A smoother pad texture creates less dishing and erosion. Therefore for advanced nodes end users prefer smoother pad texture. This can be accomplished by conditioner design or pad design or both. The logical solution from a conditioner perspective would be to reduce the diamond size.

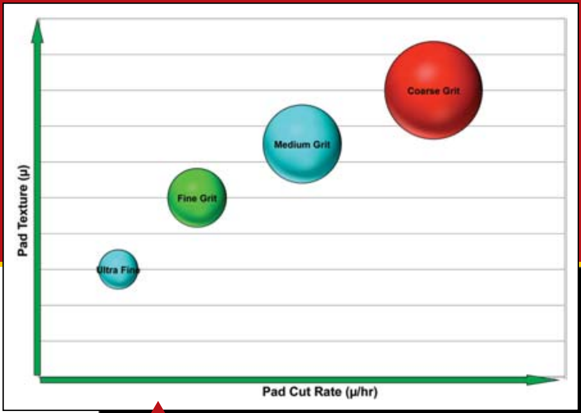
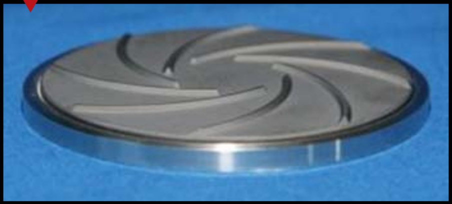


Figure 3: Pad cut Rate verses Pad Texture

Figure 4: Next Generation Conditioner Using Cutting Edges



However, there are limitations on how small the diamond can be from a manufacturing perspective, as well as, a performance perspective.

An alternative to produce smooth pad textures is to manufacture a conditioner that cuts the pad with an edge instead of with points. This is analogous to removing the surface of wood with a plane instead of sandpaper. Figure 4 shows such a conditioner that was manufacturing by an engineered surface coated with CVD diamond. This conditioner does not have any diamond grit and the active region on this conditioner is the CVD diamond coated edges, not diamond grit points.

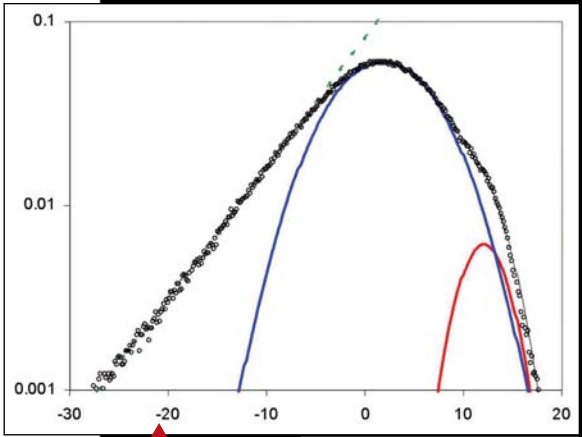
CONDITIONER TYPE AND PAD TEXTURE

An experiment was performed to investigate the effect of conditioner type on the pad texture for a copper process. A typical copper process was performed using 200-mm blanket copper wafers, IC 1020 M groove pad, 200 ml of Fujimi PL-7103 slurry + 800 ml of DI H_2O + 33 grams of 30% ultra pure H_2O_2 and four different conditioner types; coarse diamond conditioner, medium diamond conditioner, fine diamond conditioner, and a new edge design conditioner. Two metrology techniques, interferometry and laser confocal microscopy, were used to measure the pad texture in depth.

Interferometry gives a surface height distribution as depicted in figures 5. The surface height is composed of three components, an exponential component from the porosity of the pad (green), a Gaussian component from surface conditioning component (blue), and another Gaussian component from polishing effects (red). The top surface of the pad (red) is the portion that contacts the wafer and understanding the characteristics of that top surface will help bring further understanding as to what surface gives the optimized CMP performance. Secondly, is to understand the subsurface (blue) which supports the top surface giving stiffness to the top surface and effecting the interaction of the top surface to the wafer surface. For this study we will not be concerned with the underlying pore structure of the pad. The first measurement of the top surface as discussed earlier is the surface roughness of the pad as measured from the surface height distribution known as surface abruptness λ. Figure 6 show a typical surface probability curve for a CMP Pad. A value λ can be calculated by the x component of the slope of the curve when the y value is 1/e. Therefore an increase in λ means an increase in surface texture.

A similar distribution can be obtained from interferometry known as summit height distribution. Summit height distribution differs from surface height distribution because the heights are relative to mean height of the sample surface and not the total height. This gives a distribution of the asperity heights and filters out the effects from pad porosity and eliminates very small geometries. This method is a characterization of the top two regions of the pad that we are interested in studying, conditioning and polishing regimes. For the five conditioners summit height distributions were obtained. From those distributions the average height, asperity height, and % of large asperities, as defined as asperities greater than 20 μ, were determined. Figure 7 shows a plot of these two features for each of the five conditioners. The mean asperity height and larger asperities both decreases with decreasing diamond size. The edge style conditioner had slightly smaller mean asperity heights, but significantly less large asperities as expected from the knife edge type of cutting as opposed to point cutting.

Another important feature to understand besides asperity height is the shape of the top of the asperities. From interferometry a distribution of the inverse of the radius of curvature of the asperity tops can be determined. From the distribution both the mean sharpness and percentage of very sharp asperities can be determined. Figure 8 gives the results for the five conditioners tested. The trend is decreasing sharpness with decreasing diamond size. However, for the edge style conditioner the sharpness is



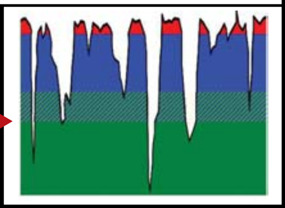


Figure 5: Three Components of Pad Texture

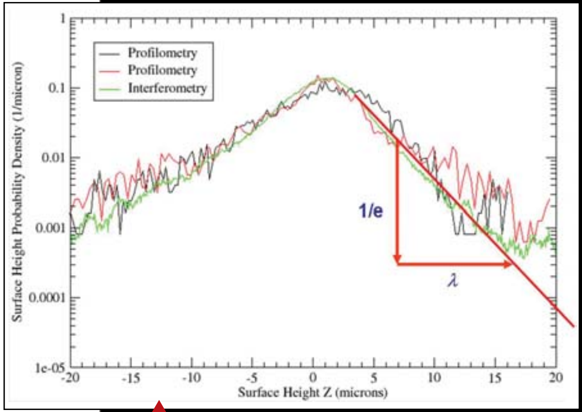


Figure 6: Surface Height Probability Density

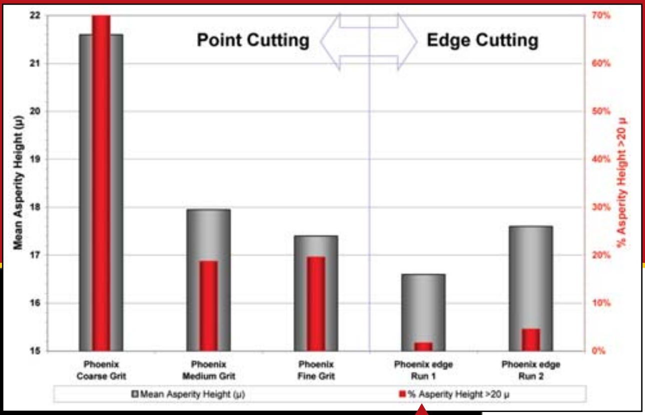
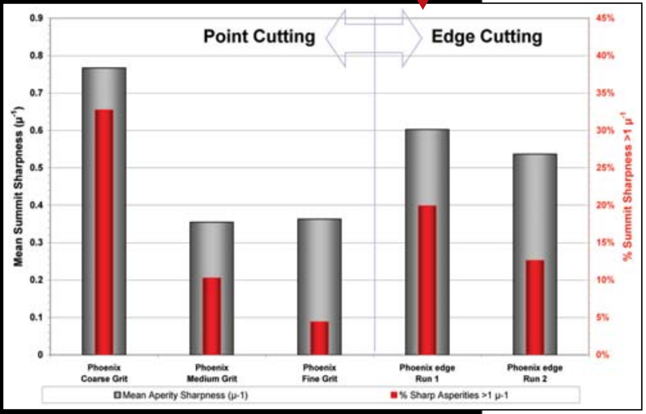


Figure 7: Mean Asperity Height and Percentage of Larger Asperities

between coarse diamond and fine diamond. It makes sense that there are different cutting mechanisms, point cutting verses edge cutting, will produce different asperity shapes.

Figure 8: Mean Asperity Sharpness & Percentage of Sharp Asperities



So far this study has been characterizing the total texture of the pad surface. We discussed the three components of the pad as it applies to the cross section of the pad. Now we will discuss the three components of the pad as it applies to the plane of the pad surface. First, contact area which is the portion of the pad asperities that is actually in contact with the wafer surface. Second, near contact area which is the region near a pad asperity where slurry can interact with the wafer surface. Finally, there is the large region of the pad which does not contact or interact with the wafer, but allows for slurry flow under the wafer. Laser confocal microscopy is a method by which you can measure the contact area of the pad. Figure 9 is one of the laser confocal microscopy images of the pad surface for a medium conditioner. The contact area regions are black, the non contact regions are grey, and the near contact regions are striped.

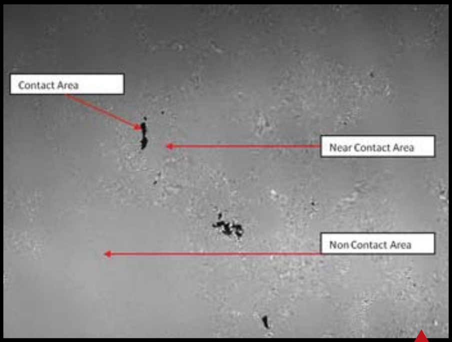
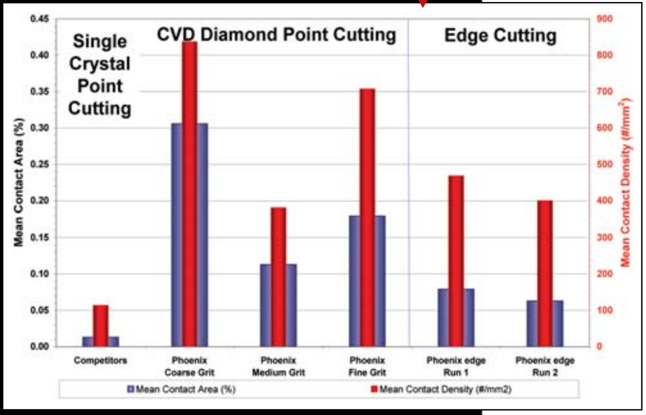


Figure 9: Example of Confocal Microscopy Image

Figure 10: Average % Contact Area and Contact Area Density



Several laser confocal microscopy images were determined for each of the five conditioners. The average area and number of contact points were determined and are depicted in figure 10. In addition, historical data for traditional conditioners that do not use CVD diamond are depicted in figure 10 as single crystal point cutting. Notice that the traditional conditioners produce very little contact area. However, the CVD diamond point cutting conditioners produce high density and high percentage contact area. The edge conditioners produce moderate % of contact area with a relatively high number of contacts. This suggests that for edge conditioners there are a lot of small contacts. This can explain the higher sharpness in figure 8 for edge conditioners. Since the contact areas are small the inverse of the radius of curvature would be high due to the size of the asperity.

Contact area size distribution can be determined from the laser confocal microscopy images. From the distributions both mean contact area size and percentage of large areas can be determined. Figure 11 shows the results for each of the five conditioners tested. For edge conditioning there are very few large areas and overall the mean size of the contact area is also small.

We have discussed total area, size, and number of contacts, but not the shape of the contact area. It was noted that the shapes of the contacts areas are different for the five conditioners. For the coarse conditioner the contact area shapes were mostly round or aspect ratio near one. For the medium grit sized conditioner there was a mixture of round and elongated contact areas. For fine grit conditioner the contact areas were predominately elongated. However, the edge conditioners produce elongated and curled shapes which were not found in the images for gritted conditioners. How the shape of the contact areas effect the CMP performance is not known, but it is only logical that it must have an effect.

COPPER PROCESS DATA

This section will discuss the copper removal rate and uniformity of the test wafer. Figure 12 gives the copper removal rate and uniformity for all five conditioners. The copper removal rate and uniformity for the three gritted conditioner was similar with a slight decrease for the fine gritted conditioner. However, it was surprising that the edge conditioner gave a 50% increase in copper removal rate without any significant increase in uniformity.

CMP process by definition is both mechanical and chemical for the removal of the desired material. Copper CMP is more chemical than mechanical. Therefore a copper process is more sensitive to small temperature changes. Likewise if the process were more mechanical then there is a higher sensitivity to coefficient of friction. Both coefficient of friction and pad temperature were measured during these blanket wafer polishing runs. Figure 13a shows that for coefficient of friction both point cutting and edge cutting have the same slope. However, the edge cutting is offset by 42%. Figure 13b gives the relationship of copper removal rate and pad temperature. Clearly the edge conditioning gives a shallower slope than the point cutting. This suggests that edge conditioning is less sensitive to temperature than point cutting. Both of these figures suggest that edge conditioning produces a different pad surface that has a different mechanism for copper removal and has the benefit of increased material removal rate with no decrease in uniformity.

Another important parameter in CMP is the pad cut rate. This is a measure of the removal of the pad surface primarily by the CMP conditioner. The ideal situation is to remove as little pad as possible and maintain as high a material removal rate as possible. This would optimize the life of the pad and optimize the throughput of wafers resulting in reducing the total cost of ownership for the process. Figure 14 gives the pad cut rates for the five conditioners. Both edge conditioners had extremely low pad cut rates. This is surprising since both edge conditioners had very high material removal rate. Historically in CMP to increase material removal rate you need a more aggressive conditioner which increases the pad cut rate. However, the edge conditioner design produces a pad surface that still provides for high material removal rate with very low pad cut rates.

DISCUSSION & RESULTS

Edge conditioners produce a smoother pad texture with fewer large asperities, a low percentage of contact area comprised of a moderate number of small contact areas with a curled elongated shape, asperities with moderate sharpness primarily due to the smaller asperity size. In addition, edge conditioners have a very low pad cut rate yet results show a 50% increase in copper removal rate. The increased copper removal rate could not be explained by either increase in coefficient of friction or an increase in pad temperature. All this suggests that the edge conditioner produces a pad surface that has a different mechanism occurring for copper removal over the conventional conditioner designs. ●

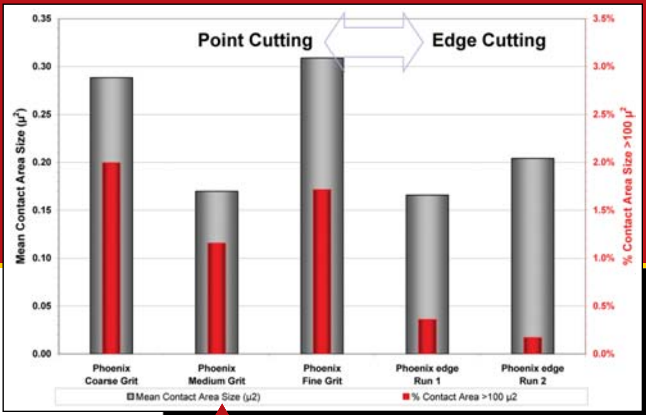


Figure 11: Mean Contact Area Size and % of Large Contact Areas

Figure 12: Copper Removal Rate and Uniformity

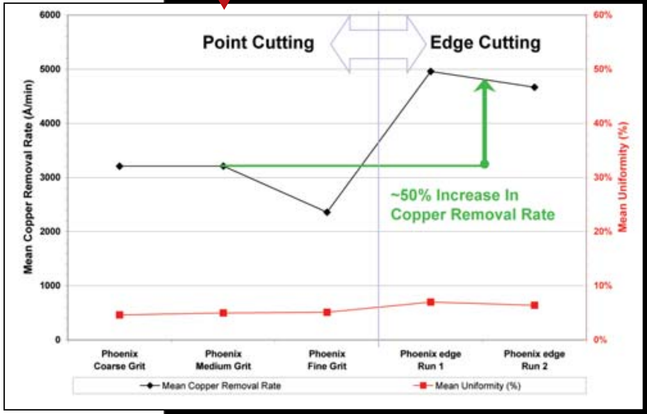


Figure 13: Relationship of Copper Removal Rate to a) COF. b) Pad Temperature

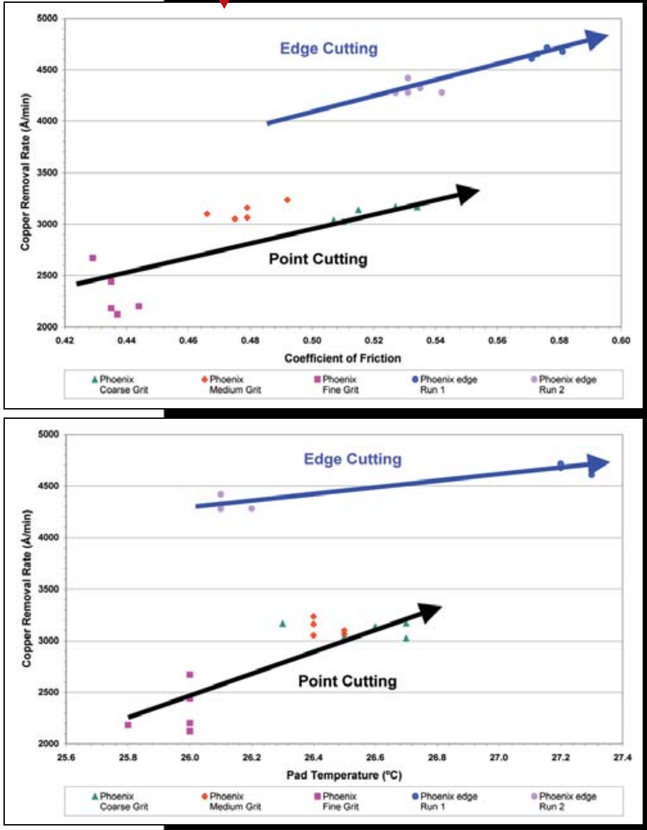
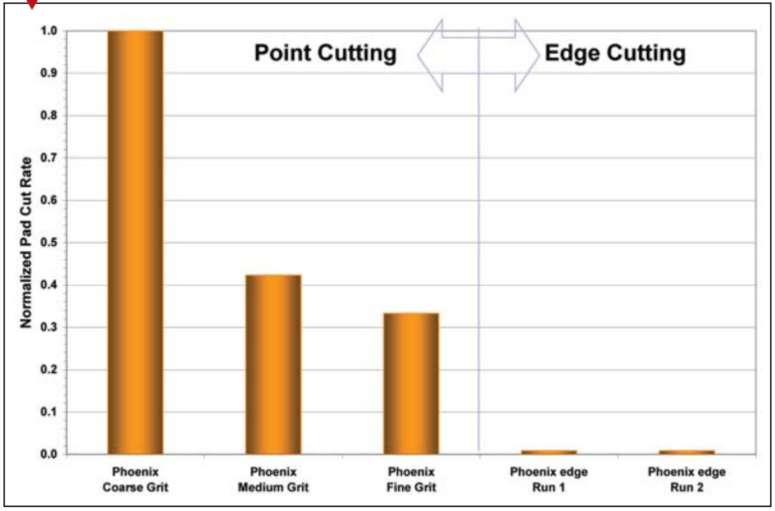


Figure 14: Normalized Pad Cut Rate



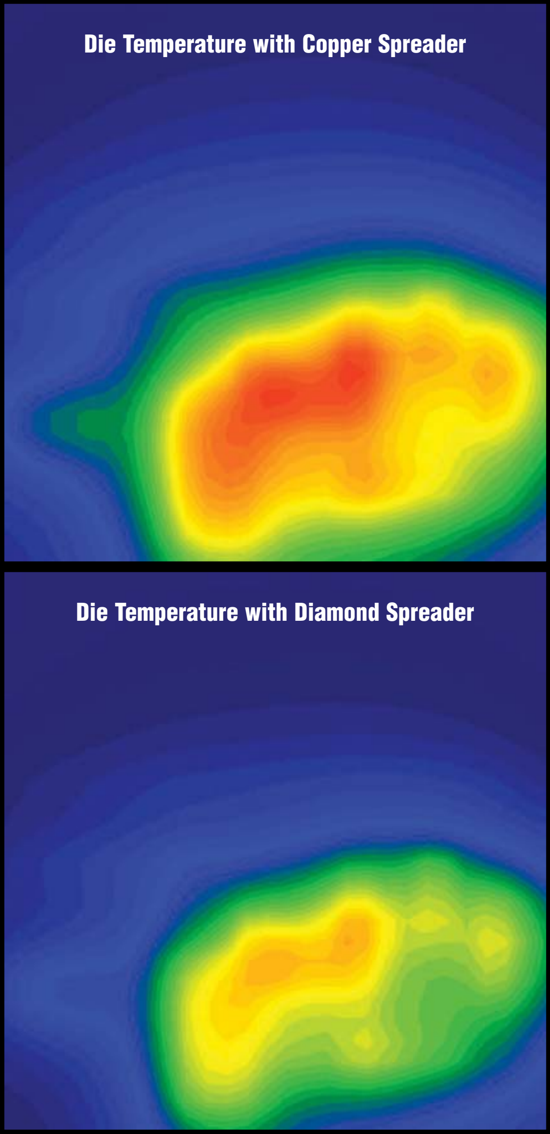
Development of High Quality, Tailored CVD Diamond Using Hot Filaments

By: Chris Engdahl, Technology Development
Crystallume Engineered Diamond Products

Deposition of diamond films through plasma chemical vapor deposition (CVD) techniques is now a routine technology and is the subject of industrial interest in the United States and abroad. In this technology, mixtures of hydrogen and methane are ionized under appropriate conditions, causing diamond films to nucleate and grow on suitable substrates. Although the plasma chemistry underlying this phenomenon is still subject of some debate, the factual basis for deposition of genuine diamond in thin or thick film has been unambiguously established. Enough empirical process technology and data on CVD diamond films have been generated to facilitate the integration of the material into selected engineering applications, with products based on the material now on the market.

Using the CVD process, continuous diamond films can be deposited on a variety of non-ferrous metals and ceramics. Materials like silicon, silicon carbide, silicon nitride, titanium, tungsten, and aluminum nitride are readily diamond coated, and diamond films grown by CVD have become important engineering materials impacting diverse areas of manufacturing. From factory floor machining in the form of diamond coated machine tools, to packaging of high power, high speed electronics in heat spreaders form with thermal conductivity four times that of copper (Figure 1), CVD diamond is a material with tangible benefits.

Other proven fields of application includes the use of diamond in fabrication of thin membranes for Microelectromechanical systems (MEMS) or lithographic masks, and the use of diamond for fabrication of high frequency Surface Acoustic Wave (SAW) filters. And the recently developed integration of CVD diamond substrate with GaN towards the development of high power HEMTs is a harbinger of more novel implementation for this unique material to critical path technologies.



Die Temperature with Copper Spreader

Die Temperature with Diamond Spreader

***FIGURE 1:** Temperature profile of the same production die mounted on copper and diamond heat spreaders.*

Thin, Smooth Diamond Films and Membranes

Image-placement distortion control is one of the most critical parameters of masks fabricated for NGL (Next Generation Lithography). Since NGL masks are fabricated on thin, non-rigid membranes, the quality of the substrate material is of utmost importance. It should possess a high degree of mechanical stiffness in order to resist any in-plane distorting forces that occur as a result of processing. A key measure of material strength is the Young's modulus of elasticity. Diamond films have a greater Young's modulus (900 GPa) than boron-doped silicon (160 GPa), silicon carbide (450 GPa) or silicon nitride (350 GPa). For example, a 1 µm thick diamond membrane is required to provide the same mechanical stiffness as a 2-µm silicon carbide or a 5-µm boron-doped silicon membrane. X-ray mask modeling work has shown that diamond membrane masks can have up to 30% less in-plane distortion than masks with silicon-carbide membranes of the same thickness. Also, in comparison to silicon nitride, with increased rigidity of a diamond membrane it will be possible to widen the grid spacing of the electron beam mask giving more usable mask area and high throughput. Furthermore, the superior thermal properties of diamond will also result in less distortion due to reduced mask heating during scanning.

Diamond films grown by conventional processes exhibit grain growth that is proportional to the thickness of the film. Grain size measured looking down at the top surface of the film is typically 30% of the film thickness. We have successfully developed a process that controls the grain size and the grain size uniformity of diamond films during growth. With this process it is possible to achieve ultra-smooth diamond surfaces. The grain size remains constant regardless of the thickness of the film up to about 2 microns. Beyond two microns, the grain size increases but grows to a much smaller size than in films deposited by conventional processes. A micrograph of the typical diamond as well as of the smooth CVD diamond film appears in Figure 2.

Characterization methods, such as SEM, AFM, and X-Ray diffraction, have demonstrated that the smooth diamond films are formed of nano-crystalline structures with average grain size of less than 10 nanometers (Figure 3). AFM characterization shows a mean roughness (Ra) of 7 to 10 nanometers (4-nm is the lowest measured). The nominal thickness of these films is 2 microns but it can be as thin as 0.1 micron with a mean roughness (Ra) of less than 4 nanometers depending on the application. Thickness uniformity is very good with thickness variations of less than 5% over the entire wafer. X-ray (Figure 4) and electron diffraction has confirmed the absence of any graphitic phase carbon.

Moderately Thick Diamond Films for SAW Applications

Diamond possess the highest value of sonic (i.e. Rayleigh wave) velocity of any material by virtue of the extreme value of its Young's modulus (~1000 GPa) and its relatively low density (3.5 gm/cm) as given by: V ~ √(G/r) where G is the shear modulus and r is density. While diamond is not piezoelectric, it can be combined with a piezoelectric material in a layered structure similar to ZnO/glass SAW devices. In this configuration, a thin piezoelectric material is deposited on top of the diamond and the electrical signal at the transducer can excite a SAW wave in the diamond. Since the energy of the SAW wave is confined to within several wavelengths of the surface, only a moderately thick (<30um) layer of diamond is needed for signal transmission.

Figure 5 is a cross sectional schematic of a diamond SAW structure. In this case about 25 microns of diamond is deposited by chemical vapor deposition (CVD) onto a standard silicon wafer, which acts as convenient structural support for the device as well as an excellent nucleation surface for the diamond. The metal transducers and a thin piezoelectric material are deposited on the surface of the diamond.

Calculations have shown that diamond SAW structures should have velocities in excess of 10,000 m/sec., depending on the piezoelectric material chosen. With sonic velocities of this magnitude, it is possible to make SAW devices operating at frequencies in excess of 2 GHz without resorting to extremely narrow line-widths. In addition, for the less advanced SAW devices operating at below 2 GHz, the use of diamond can relax the current lithography requirements, resulting in higher yields and lower cost.

High Thermal Conductivity Thick Films for Point-of-Use Heat Spreading

Integration and attachment of as-deposited thick diamond film to compound semiconductor holds the key to the successful commercialization of the next generation of high power, high frequency HEMT transistors. With that point of focus, we have succeeded in developing very high quality, high thermal conductivity on-silicon or in free-standing diamond substrates.

Of the many excitation methods available for diamond deposition, hot filament CVD has always been uniquely advantageous due to the low cost, the conformal coating of 3-D objects and the ease of scale up. Recent advancement in hardware and process development has led to deposition of material with the highest quality in terms of impurity content, electronic and optical properties, with fewer liabilities of power inefficiency and excess heat removal compared with other methods. Historically, it has been believed that other (microwave, arc-jet, etc.) enhanced CVD techniques are solely capable of producing the higher quality diamond. We present data on very high thermal conductivity CVD diamond deposited by hot filament and highly suitable for the next generation of heat-spreader in the form of ALoD (Active Layer on Diamond). Figure 6, shows a free-standing, 100-um thick, 75-mm diameter, translucent and relatively flat (peak to peak warp of ~ 400-um).

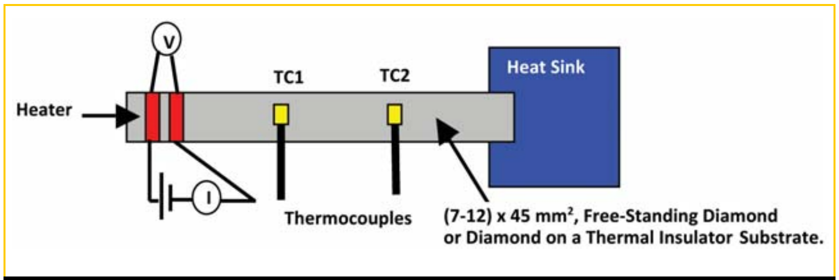

V
Heater
TC1
TC2
Heat Sink
I
Thermocouples
(7-12) x 45 mm², Free-Standing Diamond
or Diamond on a Thermal Insulator Substrate.

FIGURE 7: *The basic layout of the measured sample, heater, thermocouples and heat-sink (courtesy of CSTR technology, LLC)*

The in-plane, thermal conductivity of the material was measured in collaboration with an outside source by using simple Joule heating thermometry. The calculation is by using two simple equations that follows:

1. Thermal resistance is calculated by: $R = \Delta T/\text{Power}$
2. Thermal conductivity is calculated by: $k = L/RA$

The basic outline of the technique is presented in Figure 7.

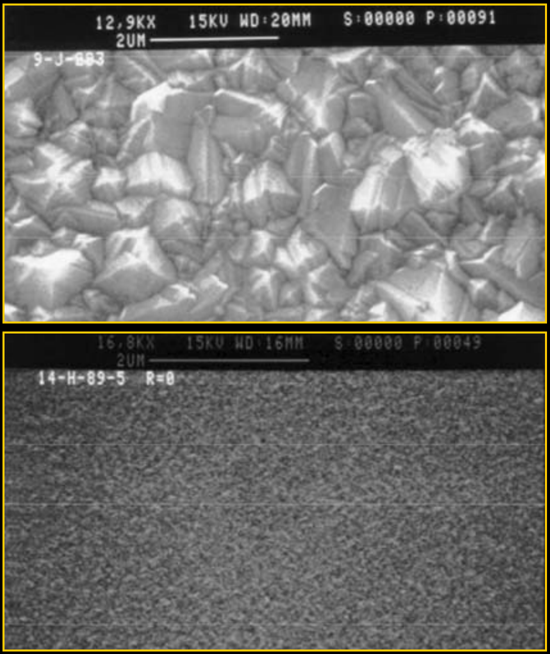

12,9KX 15KU WD:20MM S:00000 P:00091
2UM
9-J-883
16,8KX 15KU WD:16MM S:00000 P:00049
2UM
14-H-89-5 R=0

FIGURE 2: *Typical CVD Diamond Film Surface on the left. Smooth CVD Diamond Film Surface on the right.*

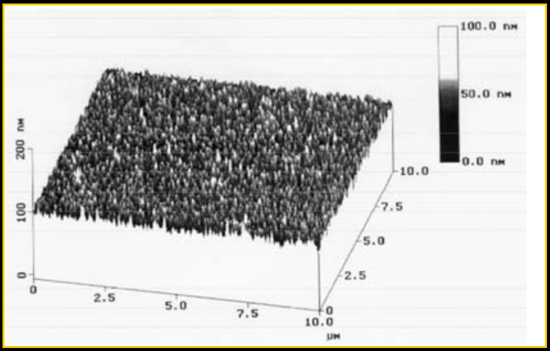


Image Statistics

Rms (Rq)	5.121 nm
Mean roughness (Ra)	4.021 nm
Max height (Rmax)	58.344 nm
Surface area	102.27 µm²

Box Statistics

Mean	0.0002 nm
Rms (Rq)	5.121 nm
Mean roughness (Ra)	4.021 nm
Max height (Rmax)	58.344 nm
Peak Thresh ref	zero
Peak Thresh(%rms)	100.00
Peak Threshold	5.121 nm
10 pt mean (Rz)	51.959 nm
Peak count	3500
Av peak height	8.663 nm
Surface area	102.27 µm²
Surface area diff	2.270 %
Summit Thresh(%rms)	10.000
Summit count	3130
Line density	9.700 /µm
Box x dimension	10.000 µm
Box y dimension	10.000 µm

FIGURE 3:

AFM Data for the Smooth Film

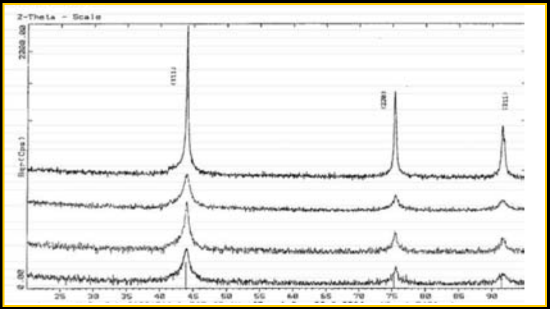


FIGURE 4: *X-ray Diffraction Spectra of Four Crystallume Diamond Films.*

The top spectrum corresponds to a large grain diamond film and is shown here for comparison. The three bottom spectra correspond to smooth diamond films. The peaks centered at: 43.9, 75.3, and 91.5 are related to orientations (111), (220), and (311) of the diamond crystal structure. No graphitic structure signals were present.

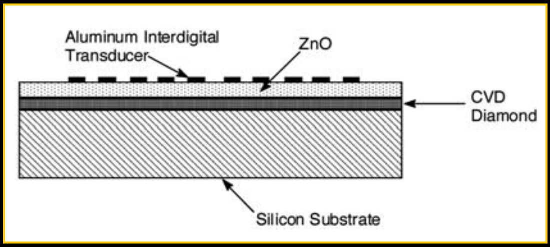


FIGURE 5:* *Schematic Cross-Sectional Diagram of a SAW Structure Incorporating a Diamond Film

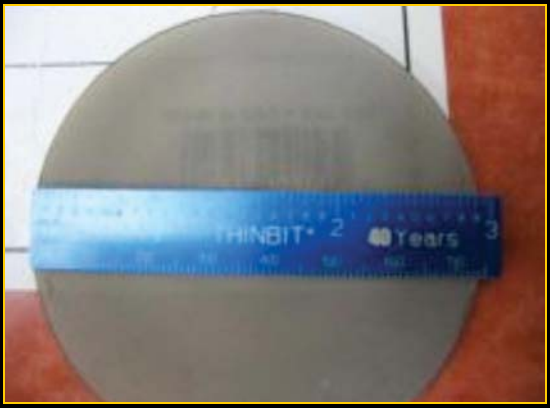


FIGURE 6:* *Hot Filament Deposited Diamond with k ~ 1300-400 w/m.K

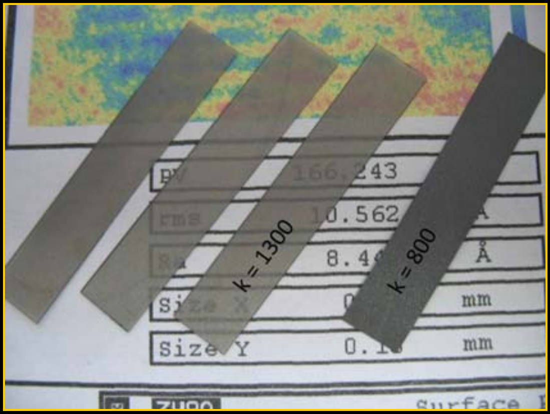


FIGURE 8:* *Material with Different k and Level of Translucence

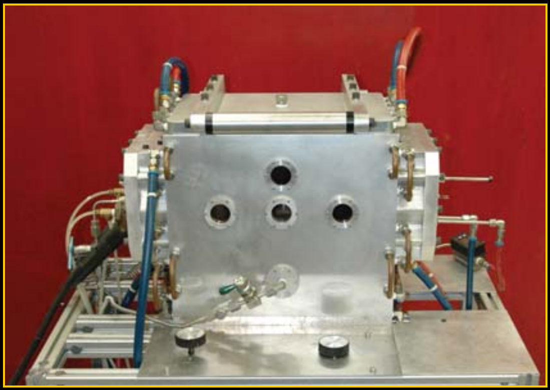


FIGURE 10:* *Single Wafer R&D Chamber

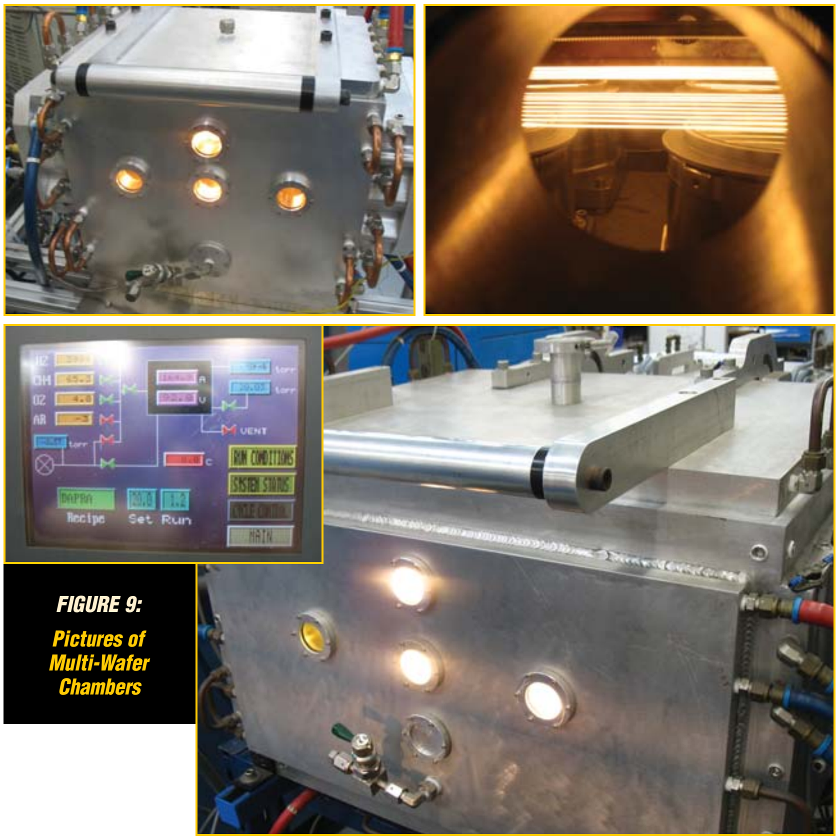


FIGURE 9:

Pictures of Multi-Wafer Chambers

WHERE:

TC1 (thermocouple 1 reading): Temperature of the spot closer to heater

TC2 (thermocouple 2 reading): Temperature of the spot closer to sink

L: The fixed distance between the two thermocouple tips

A: Cross sectional area of the diamond strip

Power (dissipated power) = IV (from measured values)

ΔT (differential temperature) = TC1-TC2 (from measured values)

The vast improvement in the quality of the film and bulk thermal conductivity is achieved by increasing atomic hydrogen density (from higher power density), while maintaining a very tight silicon substrate temperature, and reducing the methane concentration without any drastic reduction in diamond growth rate (Figure 8). Near interface thermal conductivity was improved by altering the seeding techniques and utilizing multi-step step nucleation.

The Hot Filament Chamber

We have developed and convincingly demonstrated a proprietary chamber and process for coating of multiple electronic grade substrates with extreme diamond quality. This technique has the capability to be easily adapted to a production setting, where it has the potential to bring about dramatic reductions in the cost of producing diamond coatings and films. This has been achieved by implementing the following:

1. New ultra-cooled chucks enable high power density processing.
2. Restricted the list of inert material used in the hot zone.
3. Significantly reduced the nitrogen background in the reaction chamber.
4. Dynamic heat-sinking achieved through adjustable, heat conductive, hydrogen cushion.
5. Elimination of all metal alloys from the hot zone.

The chambers are PLC controlled and operated, and the multi-wafer chambers are capable of coating four 100-mm substrates concurrently (Figure 9). A single wafer chamber (Figure 10) has also been developed and is now available for use in research and development institutions. ●

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Planned issues, topics and closing dates*:

Issue:	**Editorial Feature*:**	**Closing**
Winter 2011/2012	Superabrasives Review	Dec. 15, 2011
Spring 2012	Grinding & Machining Advancements	Mar. 31, 2012
Summer 2012	CVD Diamond & cBN	May 31, 2012
Fall 2012	IMTS Issue (Machines and New Technology)	July 1, 2012
Winter 2012/2013	INTERTECH 2013 Registration Packet	Sept. 30, 2012
Spring 2013	INTERTECH 2013 Preview	Feb. 15, 2013

***Editorial topics & closings subject to change**

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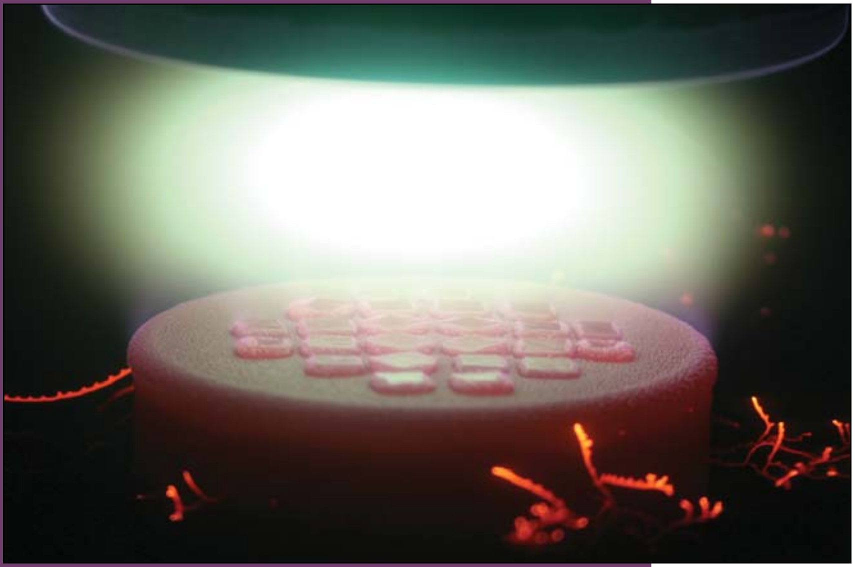
DIAMOND PRODUCTION INNOVATION
Mass Production

By: MICHAEL MCMAHON – COO
Scio Diamond Technology Corporation



The photo above shows Scio's S3532 technology. This picture shows 2, 4 5mm x 5mm seeds in the reactor growing simultaneously.

Is the real "disruptive technology innovation" of cultured diamond for the industrial world, "mass production?" Throughout the last six or seven decades man has produced, in one shape or another, "man-made" diamond. It has many names including cultured diamond, lab-grown diamond, man-made diamond, HPHT, CVD, etc. Some have even attempted to place CZ into this category.

As is the case in most industries, only a few survive. Those companies that are surviving today, few that they are, can truly make "diamond." Not natural diamond, not pretend diamond, but "REAL DIAMOND."

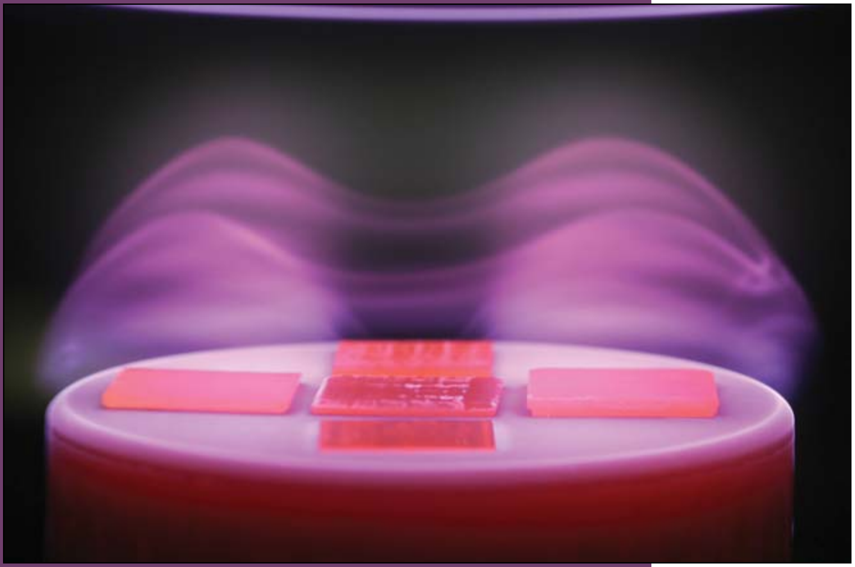
There are literally so many potential applications for industrial diamond that the demand cannot be met. Moreover, the quantities now being supplied are not being produced economically, limiting the real quantities demanded. The failure to produce economically feasible diamond for industrial use is robbing the world of the material's dynamic benefit.

The photo above shows Scio's S31M technology. This picture shows a 25mm x 25mm seed, with approximately 750 microns of growth after a single day's growth.

DIAMOND GROWTH

Scio Diamond's mission is to end the drought. Scio Diamond has just begun production of CVD Single Crystal Diamond in Greenville, SC. Its patented methodologies and processes, combined now with good manufacturing discipline, support Scio's drive to mass production. Scio has started its mass production advancement process that will culminate in the production of over 150,000 gross carats of diamond annually from less than 15 reactors. The core of this mass production drive will be the application of Scio's multiple patented growing technologies. Scio's proven process for seed replication and harvesting and Mosaic seed creation allows it to advance rapidly from its production startup of multiple diamond seeds measuring up to twenty four (5mm x 5mm) to multiple Mosaic seeds measuring at a minimum of 25mm x 25mm, in the same reactor. Note, for comparison purposes, the grow time for all runs in this article is approximately 7 days. The expected up time of the reactors is 90% or greater.

The S3532 technology is used initially for Scio's self-sustaining seed production, as well as numerous industrial uses, specifically in the cutter blade market sector. Upon completion of a S3532 growth run, each seed will yield a rough diamond of approximately 2 gross carats or up to 64 gross carats per run.



This photo shows Scio's S35M technology. The picture shows 5, 25mm x 25mm seeds, with approximately 750 microns of growth.

Following the successful completion of Scio's growth run at S3532 technology, Scio will implement its 2nd phase of proven S3724 technology. The S3724 technology is generally the same as S3532 but with differences in the seed size and the number of seeds on the growing platform. The minimum size seed in these runs is 7mm x 7mm. This technology will yield up to 92 rough gross carats per run or a 48% increase over the S3532 technology.

These two technologies are based on Scio's 3" growing platform. It should be noted that each of these technologies could be increased dramatically by changing to the 4" growing platform, thereby increasing growing capability by another 78%. The gross carat yield expectation would expand in line with that capability.

In parallel with the production runs using S3532 and S3724 technologies, Scio Diamond will be growing its larger seeds. This is accomplished by using a patented Mosaic Process.

The Scio Grown Diamond Mosaic Separation is the patented process used by Scio to replicate and then fuse multiple seed diamonds. This process allows for separation at an atomic level, making possible the production of large volume single crystals.

Depending on product demand, Scio will be progressively creating seeds in multiple bar and plate formations to adapt to customers' specific needs. This configuration will use the proven S31M and S48M technologies. Seed sizes will be created to grow product ranging from 5mm x 10mm x 1/2mm thick, to 28mm x 28mm x 5mm thick.

At full growth this diamond plate will measure 25mm x 25mm x 4-5mm thick, yielding 39-49 gross carats of diamond from each plate. The yield of 39-49 diamond gross carats is dependent on finished thickness and actual seed width and length. In addition, Scio will make customized bars of diamond focusing on specific clients, or a cluster of clients desiring similar requirements. For instance, if a 3mm x 2mm x 1mm finished diamond part is needed, Scio will optimize the growth dimensions to enable efficient fabrication of the final product.

At full growth on non-specialized runs, the S35M technology utilizing five 25mm x 25mm Scio generated seeds will produce between 195 and 245 gross carats per run.

Scio's most recent proven technology is its S48M generation (not pictured). The S48M, which begins with eight 25mm x 25mm seeds and at full growth, is 4-5mm thick, yielding between 312 and 392 diamond gross carats per run. Each of the aforementioned technologies will average approximately 45 runs per year.

FABRICATION

Given this mass production of cultured diamond for industrial uses, the need for increased capability for fabrication and polishing becomes the next hurdle. Diamond growth is not a labor-intensive business. While multiple growers, once started and in cycle, can be run by one operator, great attention to detail is needed in operating lasers and polishing operations and the ratio of labor to machine is higher.

Example: The Scio S35M technology at 1.2MM growth thickness produces approximately 55 gross carats per 3 day run. Now your client wants you to produce 3mm x 2mm x 1mm cutter blades and they need to be polished on top and bottom. How many blades can you get from (5) five, 25mm x 25mm x 1.2mm seamless diamond plates? The math tells you with a 20% kerf loss you would have approximately 400. If your client wants 1,000 of these per month, how many lasers and operators will you need to fabricate and polish for this single customer? ●

While some producers have the ability to make beautiful gemstones in varying colors and grades, the industrial need for diamond is almost beyond belief. Through research and development efforts around the world, hundreds, if not thousands, of brilliant scientists and PhD's have developed a multitude of uses for diamond in the industrial and commercial arenas. More are being developed every day.

USES

Acoustic
Crushing
Drilling
Electromechanical
Electronics
Medical
Milling
Optical
Precision Machining
Sawing
Wear Resistance

INDUSTRIES

Aerospace
Automotive
Construction
Consumer Goods
Electronics
Environmental
Healthcare
Lasers
Mining
Oil/Gas
Optics
Power / Utilities
Tunneling
Wire Forming

SUMMARY

What does all this mean to the industrial diamond market? It is GOOD NEWS! As more and more diamond is available and production is economically scalable, the hundreds of industrial applications have a much greater chance of coming to fruition for the masses and allowing the world to experience the impact of life-altering technology that diamond can bring. Through innovation and the application of proven science and technologies and matching that with GMP processes, large quantities of diamond material can be now be made economically per client requirements.

Industrial Diamond Association of America, Inc.

MEMBERSHIP APPLICATION

Company ____________________ Address ____________________

City ____________________ State ________ Zip Code/Postal Code ____________ Country ____________

Shipping Address (Can not ship to PO Box) ____________________

City ____________________ State ________ Zip Code/Postal Code ____________ Country ____________

Phone ____________________ Fax ____________________

E-mail ____________________ Web Site ____________________

Official Representative ____________________

Others (Participating in IDA Activities) ____________________

Principle Business Activity ____________________

Which applies to your company: ________ Corporation ________ Partnership ________ Sole Proprietorship

Provide names of principle officers or partners: ____________________

When was your company established? ____________

How long has your company been engaged in superabrasive/ultra-hard material industry? ________

List at least two business references which are current IDA REGULAR MEMBERS. REQUIRED for Consideration

1. ____________________
2. ____________________

CHECK APPROPRIATE MEMBERSHIP

________ **Regular Membership**

Any company and/or individual classified as a superabrasive/ultra-hard material supplier, tool maker, machine tool builder or related business which HAS an office and a local, state or province business license in the United States, Canada or Mexico is eligible for membership in this category. Only one individual shall be designated by each member company as the IDA Delegate with voting and other privileges described in the By-Laws.

(DUES CATEGORY)

The dues category for Regular Members is determined by annual sales volume expressed in US $ as indicated below. Check to appropriate category:

_____	Category 1	$2,650 per year	Over $20,000,000 Annual Sales
_____	Category 2	$1,990 per year	$10,000,000 - $19,999,999 Annual Sales
_____	Category 3	$1,750 per year	$6,000,000 - $9,999,999 Annual Sales
_____	Category 4	$1,350 per year	Under $2,000,000 - $5,999,999 Annual Sales
_____	Category 5	$995 per year	Under $1,999,999 Annual Sales

________ **International Membership**

Any company and/or individual in the diamond and/or cBN business which DOES NOT have an office and a local, state or province business license in the United States, Canada or Mexico is eligible for membership in this category. An International member shall have all the privileges of regular membership, except that he/she cannot vote at any membership meetings, participate in statistical reporting for the North American market, hold proxies or serve in any office in IDA. Annual fee for International Member is **$3990 per year**.

________ **Associate Membership**

Available for companies having a principal office in the U.S.A., Canada or Mexico, which are ***providing products or services to companies within the superabrasive/ultra-hard material industry***, but are not engaged in selling, using or dealing in industrial diamonds, cubic boron nitride, compacted diamond/cbn, diamond film or products containing diamonds/cbn. An Associate member shall have all the privileges of regular membership, except that the Delegate cannot vote at any membership meetings, participate in statistical reporting for the North American market, hold proxies or serve in any office in IDA. Annual fee for an Associate is **$515 per year**.

________ **End User/Contractor Membership**

Available for any global companies or individuals, which USE products classified as superabrasives or ultra-hard materials, but are *NOT ENGAGED IN SELLING* industrial diamonds, cubic boron nitride, compacted diamond/cbn, diamond film or products containing diamonds/cbn. An End User/Contractor member shall have all the privileges of regular membership, except that the Delegate cannot vote at any membership meetings, participate in statistical reporting for the North American market, hold proxies or serve in any office in IDA. Annual fee for an End User/Contractor is **$386 per year**.

________ **Academia/Research Membership**

Any non-profit Academic institution or R & D organization is eligible for membership in this category. An Academia/ Research/ member shall have all the privileges of regular membership, except that the Delegate cannot vote at any membership meetings, participate in statistical reporting for the North American market, hold proxies or serve in any office in IDA. Annual fee for Academia/Research is **$155 per year**.

________ **Student Membership**

Any FULL TIME Student *NOT ENGAGED IN SELLING* industrial diamonds, cubic boron nitride, compacted diamond/cbn, diamond film or products containing diamonds/cbn is eligible for membership in this category. A Student shall have all the privileges of regular membership, except that he/she cannot vote at any membership meetings, participate in statistical reporting for the North American market, hold proxies or serve in any office in IDA.Annual fee for a Student Membership is **$77 per year**.

________ **Senior Membership**

Any individual who has worked for and/or retired from an IDA Member company or is no longer active in the diamond or CBN business is eligible for membership in this category. A senior member shall have all the privileges of regular membership, except that he/she cannot vote at any membership meetings, participate in statistical reporting, hold proxies or serve in any office in IDA. Annual fee for a Senior is **$52 per year**.

Name of Delegate Member: ____________________

Title: ____________________

E-Mail: ____________________

**** Applications for ALL Memberships are reviewed by the Board of Directors and must be approved by a two-thirds vote.***

________ **Affiliate Membership**

Each company that enrolls as an IDA Member is entitled to have a second person at that company designated an Affiliate Member. The first Affiliate member will receive IDA material at no further cost. Additional persons at Member companies can be added as Affiliate Members to receive IDA materials. Annual fee for additional Affiliates is $98 per person. Name of 1st Affiliate Member (no charge):

Name of 1st Affiliate Member (no charge): ____________________

Name of 2nd Affiliate Member ($98): ____________________

Name of 3rd Affiliate Member ($98): ____________________

If your company wants more Affiliate Members, please attach additional sheets.

WHAT IS THE IDA?

***The Industrial Diamond Association of America, Inc.* is a non-profit trade association and was incorporated on March 29, 1946 in the State of New York. It is the oldest and most prestigious association in the superabrasive/ultrahard materials industry. Activity and focus has evolved from natural diamond to superabrasives and most recently, to all ultrahard materials including CVD Diamond. Members include material suppliers, tool manufacturers, component producers, machine tool builders, end users, academia/research affiliates and other companies related to the research, manufacture, application, use and sales of superabrasives.**

WHAT DOES THE IDA DO?

- Oversees Statistics Reporting Program
- Establishes Industry Standards
- Interacts With Global Associations And Organizations
- Creates And Distributes Market Studies & Data
- Organizes And Presents Technical Seminars & Conferences
- Serves As A Government Liaison For Industry Guidelines And Regulations
- Participates As Member Of World Diamond Council
- Provides Safety / Regulatory Reports And Advisement
- Resource For General Information And Consultation

OTHER MEMBER SERVICES

- PUBLISHES QUARTERLY MAGAZINE
- HOLDS ANNUAL CONVENTIONS
- HOSTS IDA WEBSITE WITH MEMBER FOCUS AND DIRECTION
- PROVIDES SPECIFIC ASSISTANCE ON INDIVIDUAL MEMBER ISSUES
- CREATES AND DISTRIBUTES PUBLICATIONS ON PRODUCTS AND APPLICATIONS
- ACTS AS A COLLECTIVE VOICE FOR INDUSTRY CONCERNS

FAX completed membership form to 614-797-2264

Cubic Boron Nitride (cBN) Composite Coating, TuffTek® for Carbide and Ceramic Tools

Updates on Breakthrough Innovation for Advancing Applications Paradigm

Wenping Jiang, Director of Manufacturing, NanoMech Inc.
Ajay P. Malshe, Chief Technology Officer and Founder, NanoMech Inc.

INTRODUCTION

Cubic boron nitride (cBN) nano and micro particles integrated composite coating with trade name of TuffTek®, as an innovative route to realize thick functional cBN coating (>4 µm) with superb adhesion, have demonstrated excellent performance (tool life and workpiece surface finish) in machining range of parts from ferrous materials, powder metals, wood composites with abrasive particles, polymeric composites, and even great application potential in machining high-temperature alloys. Particularly, through these patented and patent pending technologies, the composite coating on carbide inserts in continuous turning AISI 4340 hardened steel with hardness of 50~54 Rc has produced tool wear rate, (tip-to-tip comparison), similar to that of polycrystalline boron nitride (PCBN) tipped inserts, and performance superior to state-ofthe- art precisely ground bulk Al_2O_3 inserts including the ones with PVD coating. In this follow up brief case study, a brief discussion on the most recent breakthrough development of cBN composite coating is included. Additionally, a case study in continuous turning AISI 4340 hardened steel (<54 Rc) is incorporated. The case study uses cBN composite coated carbide inserts compared to benchmark of bulk Al_2O_3 inserts (with about 30% TiC) from three different manufacturers at customers' typical application condition.

MOST UPDATED COATING DEVELOPMENT

For coating architecture, in addition to early single phase infiltrant such as TiN, TiC and TiCN, the composite coatings with multiple infiltrants and architectured in stacked layered structure including oxide phases have been added to new generation of TuffTek® product family to meet customers' desire for high productivity. A typical example of such coating configuration is shown in Figure 1. In this layered patented coating structure, a composite coating of cBN particles (density as high as 65~70%), as a thermal barrier layer, and a transitional layer are evident. While the early single infiltrant composite coating has delivered impressive application-specific need, the layered coating architecture is significantly expanding advanced application spectrum.

To further enhance the machining productivity, the composite coating has been successfully applied to ceramic inserts such as bulk Al_2O_3 and Si_3N_4 inserts for its respective applications. As evident in Figure 2, a well adherent cBN composite coating as thin as 3 µm was applied to bulk

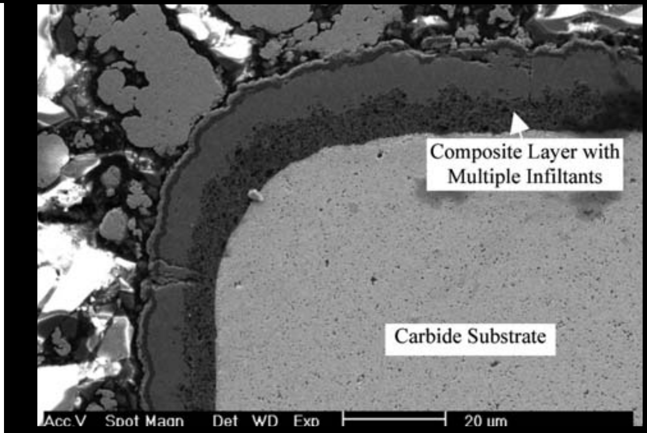

Composite Layer with Multiple Infiltants
Carbide Substrate
Acc.V Spot Magn Det WD Exp
20 µm

FIGURE 1: ***SEM micrograph showing the cross-section of a typical layered structure of cBN composite coating.***

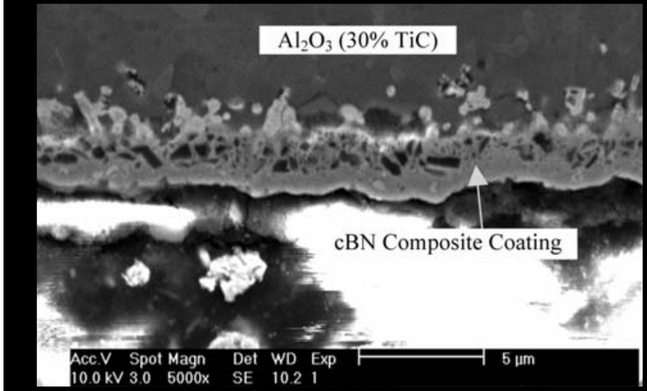


FIGURE 2: ***SEM micrograph showing a thin cBN composite coating on bulk Al2O3 inserts.***

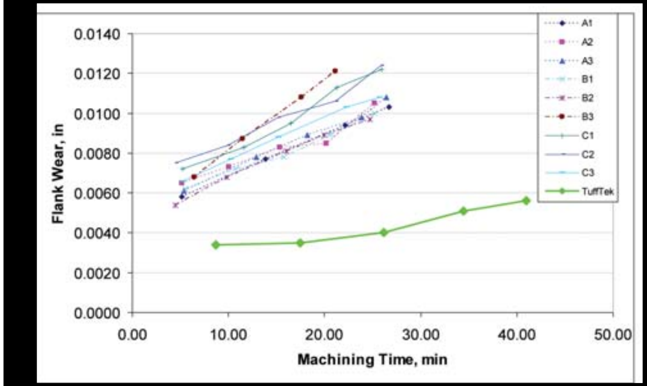


FIGURE 3: ***Graph showing flank wear progression of cBN composite coated carbide inserts vs. Al_2O_3 bulk inserts from three different suppliers (A, B and C).***

Al_2O_3 inserts. In turning 8620 case hardened steel (~58 Rc), breakthrough coating architecture has extended tool life as much as 80%.

CASE STUDY

Turning AISI 4340 hardened alloy steel is known for excessive crater wear, flank wear, and notch generation due to work hardening. Typical cutting tools for such machining includes PCBN tipped inserts or PCBN bulk inserts, Al_2O_3 bulk inserts in its precisely ground form or with PVD coating, and CVD multiple-layer coating carbide inserts. Depending upon turning conditions and specific hardness of the workpieces, PCBN inserts and Al_2O_3 based inserts are the primary choices. In this application sector, the cBN composite coating on carbide inserts offers unique advancement with enhanced tool performance (crater and flank wear resistance) and big cost saving, ROI. Figure 3 shows the tool wear progression of cBN composite coating (TuffTek®) in comparison to bulk Al_2O_3 inserts, from three different best suppliers A, B and C, for continuous turning 4340 hardened steel (51~54 Rc) at V=150 m/min, f=0.15 mm/rev, DoC=0.25 mm with cutting fluid. The inserts from A and C are with PVD TiN coating. Based on the results, we can conclude (A) all the ceramic bulk inserts have higher flank wear than that of TuffTek® coated inserts; (B) TuffTek® has much lower wear rate than the ceramic inserts. The low flank wear helps to hold tight dimensions of workpieces. Optical analysis of the tool wear demonstrated an even abrasive wear on both flank and crater surfaces (Figure 4A and B), while ceramic inserts experienced excessive flank wear and crater wear (Figure 4C and D). ●

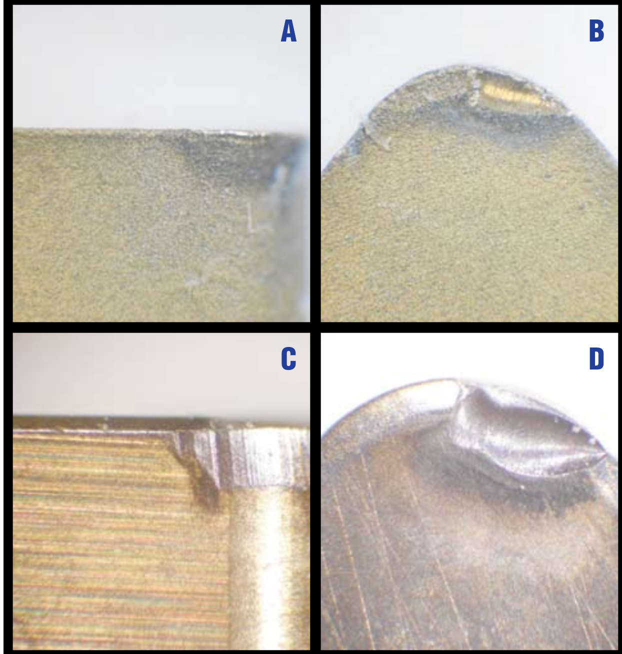


***FIGURE 4:** Optical images showing TuffTek® coated inserts (A & B) and bulk Al203 inserts with PVD TiN coating (C & D)*

SUMMARY: New architectures of cBN composite coatings have offered flexibility to coat carbide inserts as well as ceramic inserts. Depending on different applications, they can be configured with either single infiltrant phase or multiple infiltrant phases allowing unique architectures. The composite coatings produce superb tool life in comparison to benchmark bulk ceramic inserts in continuous turning 4340 hardened steels. They provide manufacturing industries a cost-effective solution for high productivity and improved workpiece tolerance.

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